THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE PERMANENT SECRETARY OF THE GEOLOGICAL SOCIETY.

Quod si cui mortalium cordi et curæ sit non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant. —*Novum Organum, Præfatio.*

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SOLD ALSO AT THE APARTMENTS OF THE SOCIETY.

MCMXVIII.

List

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Elected February 16th, 1917.

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PROCESS-BLOCKS AND OTHER ILLUSTRATIVE FIGURES

BESIDES THOSE IN THE PLATES.

Dates of Issue of the Quarterly Journal for 1917.

No. 289—April 6th, 1918.
No. 290—August 20th, 1918.
No. 291—November 30th, 1918.
No. 292—December 31st, 1918.

Errata and Omissa.

Page 16, third line from the top, after the word 'felspar,' the following sentence has been omitted: 'The laths of the ground-mass appear to be unaltered.'

Page 53, line 25 from top, *for* 'Pl. IV, fig. 13' *read* 'Pl. IV, fig. 11.'

Page 104, in the first column of table, *for* 'D_3' (above the words *Dibunophyllum θ*) *read* 'D_1.'

PROCEEDINGS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

SESSION 1916–17.

November 8th, 1916.

Dr. ALFRED HARKER, F.R.S., President,
in the Chair.

The List of Donations to the Library was read.

The Names of certain Fellows of the Society were read out for the first time, in conformity with the Bye-Laws, Sect. VI, Art. 5, in consequence of the Non-Payment of the Arrears of their Contributions.

The PRESIDENT referred to the loss which the Society had sustained during the recess by the decease of its Treasurer, Mr. BEDFORD MCNEILL, A.R.S.M., M.Inst.M.M., A.M.Inst.C.E. He spoke of Mr. McNeill's eminence in his profession, and of the services that he had rendered to the Society as a Member of Council for many years, and as Treasurer since 1912. The President mentioned that the Society was well represented at the funeral, and added that he felt sure that the Fellows would associate themselves with the resolution of condolence and sympathy which the Council had addressed to Mrs. McNeill.

The following communication was read :—

'*Aulina retiformis*, gen. et sp. nov., *Phillipsastræa hennahi* (Lonsdale), and the Genus *Orionastræa*.' By Stanley Smith, B.A., D.Sc., F.G.S.

Mr. J. W. JACKSON exhibited a number of facetted pebbles from Pendleton (Lancashire), and stated that nearly 200 of these

had been collected during the last six months from near the top of a section of current-bedded and faulted Glacial Sand and Gravel at an altitude of about 200 feet O.D.

The pebbles occur *in situ* some 2 or 3 feet below the capping of darker subsoil, which contains cores and flakes of flint, including pigmies. They consist of slate, granites (Eskdale and Shap), Ennerdale granophyre, Borrowdale volcanic tuffs, porphyries, quartzites, Millstone Grit, sandstones, Chalk flints, Carboniferous chert, and other rocks.

The largest facetted pebble measures $11\frac{1}{2} \times 8\frac{1}{4}$ inches, and is 7 inches high; the smallest is only half an inch in diameter.

The facets are generally concave, grooved, or fluted. They vary in number: some stones have one facet only, others two or more. One stone with a flat top shows five incipient facets. On some the grooving is of the nature of parallel series of elongated pits.

Differentiation, according to varying hardness and composition, is well displayed on the granites, porphyries, grits, etc., where the weaker constituents have been strongly eroded, leaving the stones with an irregularly pitted surface.

The production of facets by splitting along joint-planes is seen on some examples of sandstone; but the facet thus formed has been modified by wind-action.

A few pebbles occurred in the sand completely inverted, and show some distinct facetting on both sides.

Of examples orientated *in situ*, the facets faced north-westwards, westwards, and south-westwards—the directions of the present prevailing winds.

All the pebbles are of Glacial origin, but the facetting may be relatively quite recent. The upper part of the sands where they occur may be the result of redistribution by wind before a soil-cap began to form.

A series of polished specimens of Palæozoic corals was exhibited by W. F. Gwinnell, B.Sc., F.G.S.

A geological map of British Guiana, 1913 (1 : 633,600, or 1 inch = 10 miles), presented by the Secretary of State for the Colonies; and twelve sheets of maps published and presented by the Geological Survey of Japan, 1916 (1 : 400,000), were also exhibited.

Numerous books and pamphlets from the Library of R. D. Oldham, F.R.S., V.P.G.S., were exhibited. These formed a selection of an extensive series of publications, relating chiefly to seismology, that Mr. Oldham recently presented to the Society.

November 22nd, 1916.

Dr. ALFRED HARKER, F.R.S., President,
in the Chair.

Stanley Charles Hooper Blandford, F.S.I., Stud.Inst.M.M., Coronel, Chile (South America); and Herbert Kilburn Scott, M.Inst.M.M., Jacutinga, Chesham Bois (Buckinghamshire), were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communication was read:—

'Characeæ from the Lower Headon Beds.' By Clement Reid, F.R.S., F.L.S., F.G.S., and James Groves, F.L.S.

The Names of certain Fellows of the Society were read out for the second time, in conformity with the Bye-Laws, Sect. VI. Art. 5, in consequence of the Non-Payment of the Arrears of their Contributions.

Lantern-slides, photographs and specimens of Characeæ from the Lower Headon Beds were exhibited by Clement Reid, F.R.S., F.L.S., F.G.S., and James Groves, F.L.S., in illustration of their paper.

A Palæolithic flint-implement, found in the British trenches near Bray, was exhibited by W. Whitaker, B.A., F.R.S.

A Geological sketch-map of Tasmania, based on a map by B. M. Johnston, and revised by the Geological Survey of Tasmania (scale: 1 inch = 15 miles), 1914, was also exhibited.

A Special General Meeting was held on Wednesday, November 22nd, 1916, at 5.15 P.M. (before the Ordinary Meeting), when James Vincent Elsden, D.Sc., was elected a Member of Council and Treasurer in place of the late Mr. Bedford McNeill.

December 6th, 1916.

Dr. ALFRED HARKER, F.R.S., President,
in the Chair.

William Ernest Hadford Burton, Wrenfield, Berlin Street, St. John's, Wakefield; Colin Clegg, More Hall, Bolsterstone, near Sheffield; William Edmund Cutler, Calgary, Alberta (Canada); Hugh Peter William Giffard, B.A., B.Sc., Chillington, Wolverhampton; Leonard Hawkins, M.Sc., 26 Holyrood Quadrant West, Glasgow; Daniel Franklin Higgins, M.S., care of the British Legation, Peking (China); Major John Sidney Kitson, 9 Smith Street,

Thornbury, Melbourne (Victoria); William Pickup, President of the Manchester Geological Society, Carlton Lea, Billinge End, Blackburn; Lancelot Arthur Basil Sharpe, B.A., 26 St. Margaret's Road, Oxford; William Walter Smithett, 34 Molyneux Park, Tunbridge Wells; Judge Frederic Gordon Templer, The Hall, Egglescliffe, R.S.O. (County Durham); Ernest Sterne Usher, 37 Moor Street, Fitzroy, Melbourne (Victoria); William Rupert Alfred Weatherhead, B.Sc., The University, Edmund Street, Birmingham; James Watt, W.S., 24 Rothesay Terrace, Edinburgh; and Edward Walker, M.Sc., 52 Queen's Road, St. John's Wood, N.W., were elected Fellows of the Society.

The List of Donations to the Library was read.

Mr. G. C. Crick, A.R.S.M., F.G.S., gave an account of some recent researches on the belemnite animal. He stated that it was not his intention to deal that evening with the homologies of the belemnite shell or with the phylogeny of the belemnite group, but to confine himself to the restoration of a typical belemnite animal and its shell, as shown particularly by examples in the British-Museum collection.

He first demonstrated, by means of a rough model, the construction of the belemnite shell, including the guard or rostrum, the phragmocone with its ventrally-situated siphuncle, and its thin envelope the conotheca, with its forward prolongation and expansion (on the dorsal side) known as the pro-ostracum. He then exhibited photographic slides of examples in the British-Museum collection showing these various characters, and noted the abrupt termination of the chambered cone on the lower part of the pro-ostracum, of which the dorsal surface may have been partly or almost completely covered by a thin forward extension of the guard. To illustrate what was known of the complete body of the animal as found associated with the guard, he then showed photographic slides of two of the examples figured by Huxley in his 'Memoir on the Structure of the Belemnitidæ' published in 1864. Each of these exhibited the guard associated with portions of the pro-ostracum, the ink-bag, and the hooklets of the arms. The form of the hooklets with their thickened bases was discussed, this feature in a great measure justifying the attribution to the belemnite of certain cephalopod remains (found practically at about the same geological horizon) that included uncinated arms associated with an ink-bag, and frequently also with nacreous portions of (presumably) the pro-ostracum.

Of the remains of uncinated armed cephalopods from the Lias, each exhibiting the same form of hooklets as those figured by Huxley, he said that the British-Museum collection contained seventeen examples, all from the neighbourhood of Lyme Regis and of Charmouth, in Dorset. Each specimen exhibits a number of uncinated arms associated usually with an ink-bag, sometimes also with nacreous matter, and in two instances also with the guard or

rostrum. These two examples were those to which he had already referred as having been figured by Huxley, and unfortunately the arms are not well preserved in either of these specimens; in one (*B. bruguierianus*, from the Lower Lias near Charmouth) there are only a few scattered hooklets, while the arms of the other (*B. elongatus*, from the Lower Lias of Charmouth) are represented only by a confused mass of hooklets. Of the other fifteen examples, in one there are a few solitary hooklets; in another the number of the arms is very indistinct; in two the remains of only two arms are preserved; in one there are traces of three arms; in two there are indications of three, or possibly four, arms; in one there is a confused mass of possibly four arms; and in one there are the remains of four, or possibly of five, arms. In each of the remaining six specimens six arms can be more or less clearly made out, while there is not a single example in which more than six uncinated arms are displayed.

Of the six examples that exhibit six uncinated arms four are stated to be from the Lias of Lyme Regis: one is from the Lias of Charmouth; and one was obtained from the Lower Liassic shales between Charmouth and Lyme Regis. From a consideration of these specimens, the speaker concluded that the cephalopod represented by these uncinated arms is the animal known as the belemnite, and that the six uncinated arms were arranged in three pairs of unequal length, of which the longest pair was lateral, the medium-sized pair probably dorsal, and the shortest pair probably ventral. He considered the presence of tentacular arms to be doubtful. These observations were in accord with those of Huxley, who, in his 'Memoir' already cited, stated that he had 'not been able to make out more than six or seven arms in any specimen, nor has any exhibited traces of elongated tentacula, though the shortness of the arms which have been preserved would have led one to suspect their existence.'

The speaker regarded certain markings sometimes to be seen on the guard as indicating that during the life of the animal the guard was almost, if not entirely, covered by the mantle, in which case it was highly improbable that the guard was pushed into the soft mud of the sea-bottom in order to act as an anchor.

He considered the animal to have been a free swimmer, swimming forward ordinarily, but when desirable, capable also of sudden and rapid propulsion backwards.

A short discussion followed, and the thanks of the Fellows present were accorded to the Lecturer.

Lantern-slides and specimens of belemnites were exhibited by Mr. G. C. Crick in illustration of his lecture.

A geological map of Mysore, compiled from the Records of the Department of Mines & Geology, Mysore (scale: 1 inch = 8 miles), 1915, was also exhibited.

December 20th, 1916.

Dr. Alfred Harker, F.R.S., President,
in the Chair.

The List of Donations to the Library was read.

Marie C. Stopes, D.Sc., Ph.D., gave an account of some recent researches on Mesozoic 'Cycads' (Bennettitales), dealing particularly with recently-discovered petrified remains which reveal their cellular tissues in microscopic preparations. To make the significance of the various fossil forms clear, the Lecturer first showed some lantern-slides of living Cycads, and then pointed out that it was in their external features and in their vegetative anatomy only that the fossil 'Cycads' were like the living forms: the most important features, the reproductive organs, differ profoundly in the two groups, and the fossils were fundamentally distinct, not only from the living Cycads, but from all other living or fossil families.

The fossils representing the group that are most frequently found are (*a*) trunks, generally more or less imperfect casts or partial petrifactions, and sometimes excellent petrifactions preserving anatomical details and cell-tissues; (*b*) impressions of the foliage. Not infrequent are the detached impressions of incomplete 'flowers' or cones, of one cohort (the Williamsoneæ), while petrified fructifications are numerous in some of the well-petrified trunks of the Bennettiteæ. The described species of the group run into hundreds, but probably many of these duplicate real species, because the foliage, trunks, pith-casts, various portions of the fructifications, etc., have often been separately found and named. In very few cases have the different parts been correlated. The species of the foliage are the most generally known, as they are the most readily recognized with the naked eye; they have been described under a variety of generic names.

The following table gives the proved, or probable, associated parts of some members of the group:—

Foliage.	Trunk.	Fructifications.
Zamites spp.	*Bennettites* spp.	*Bennettites* spp.
Zamites gigas.	Attached, no separate name.	*Williamsonia gigas.*
Otozamites sp.	....	*Williamsonia spectabilis.*
Ptilophyllum pectinoides.	....	*Williamsonia whitbiensis.*
Anomozamites minor.	(Only slender branches known, no name.)	*Wielandiella angustifolia.*
Tæniopteris vittata.	....	*Williamsoniella coronata.*

The Lecturer exhibited microphotographic slides of the stem and leaf-base anatomy of the group, including some unpublished details of *Bennettites maximus*. The roots of the group have hitherto been entirely unknown, and a slide was exhibited for the first time

showing rootlets penetrating the leaf-bases of a petrified specimen (represented by a section in the Geological Department of the British Museum—Natural History). These roots probably belong to *Bennettites saxbyanus*; they are covered with wonderfully-petrified root-hairs, running uncollapsed through the silica matrix. They raise interesting questions concerning the possible chemical conditions of the infiltration of the silica. Illustrations were also exhibited of the famous complex 'flower' and cone-structures, and of Wieland's brilliant restorations of the same.

Microphotographic slides were exhibited of the seed-cone of an interesting unpublished new species from the British Gault. This is beautifully petrified, and adds to our knowledge of the finer anatomy of the seeds and associated structures. It is also the largest cone of the Bennettitales yet known, though it occurs in the Gault, by which time the group appears to have begun rapidly to die out.

The following table illustrates the distribution of a few of the most interesting representatives of the Bennettitales (including the cohorts Bennettiteæ and Williamsoneæ):—

Upper Cretaceous.	Very fragmentary and uncertain records; apparently the group is nearly or quite extinct.	
Middle Cretaceous: Gault.	The new large-sized seed-cone. *B. morierei* ♀ (? described originally from the Jurassic).	
Lower Cretaceous: Lower Greensand.	Well-petrified trunks with fructifications. *B. gibsonianus* (type-species of the Bennettiteæ). *B. maximus.*	Throughout these periods in America, trunk-remains very abundant, often petrified and with fructifications, particularly from the Black Hills, South Dakota, and Maryland, *C. jenneyana*, *C. ingens*, *C. wielandi*, etc.
Potton Sands.	Trunks, e.g. *Colymbetes edwardsi.*	
Wealden.	Trunks (casts and petrifactions), foliage. *B. saxbyanus.*	
Jurassic: Purbeck.	Trunks (casts and semi-petrifactions). Buckland's original *Cycadeoidea* spp. *C. gigantea.*	
Oolites.	Trunks, pith-casts, etc. Much foliage of various types. *Williamsonia gigas* and other fruit-impressions. *W. scotica.*	
	Williamsoniella coronata.	Rich impressions in Mexico of *Williamsonia* and many foliage genera.
Lias.	Foliage and *Williamsonia*-fruits (India).	
Rhætic.	*Wielandiella angustifolia* and foliage.	

This group is by far the most characteristic of all the plants of the Jurassic and Lower Cretaceous, during which periods its distribution was almost world-wide. It was locally, if not universally, dominant, and was the most highly evolved plant-group of the epoch of which we are cognizant.

Three chief points of interest are to be noted in the geological distribution of these plants: (*a*) that the most numerous highly-specialized trunks reach their maximum in the Jurassic and Lower Cretaceous Periods, when their distribution was practically world-wide; (*b*) that the oldest and therefore presumably the most primitive type, *Wielandiella*, is externally less like the living Cycads than the commoner later forms, while these latter are utterly unlike the living genera in their fructifications; (*c*) that the geologically youngest cone is the biggest yet discovered, occurring in the Gault when the extinction of the group appears already to have set in.

Contrary to what might have been anticipated from their external likeness to the living Cycads, coupled with their great geological age, the fossil 'Cycads' are much more complex and on a higher level of evolution than the living group. It seems to be extremely unlikely that the fossil and the living forms have any direct phylogenetic connexion nearer than a remote, unknown, common ancestor. The mooted connexion between the fossil 'Cycads' and the Angiosperms is highly suggestive, but lacks data for its establishment.

A short discussion followed, and the thanks of the Fellows present were accorded to the Lecturer.

January 10th, 1917.

Dr. Alfred Harker, F.R.S., President,
in the Chair.

The List of Donations to the Library was read.

The following Fellows of the Society, nominated by the Council, were elected Auditors of the Society's Accounts for the preceding year:—Bernard Smith, M.A., and Samuel Hazzledine Warren.

The following communications were read:—

1. 'On the Palæozoic Platform beneath the London Basin and Adjoining Areas, and on the Disposition of the Mesozoic Strata upon it.' By Herbert Arthur Baker, B.Sc., F.G.S. With an Appendix by Arthur Morley Davies, D.Sc., F.G.S.

2. 'Balston Expedition to Peru: Report on Graptolites collected by Capt. J. A. Douglas, R.E., F.G.S.' By Charles Lapworth, LL.D., M.Sc., F.R.S., F.G.S.

Lantern-slides were exhibited by Dr. A. M. Davies, A.R.C.Sc., F.G.S., in illustration of Mr. H. A. Baker's paper.

Specimens of graptolites from the Inambari district of Peru, collected by Capt. J. A. Douglas, were exhibited in illustration of Prof. C. Lapworth's paper.

A fragment of garnet-pyroxene rock, enclosing an octahedral crystal of diamond, was exhibited by Capt. H. M. Luttman-Johnson, R.E., F.G.S. This specimen was found in the Roberts-Victor Mine (Orange Free State), and formed part of the larger piece of rock described by Dr. G. S. Corstorphine.[1]

January 24th, 1917.

Dr. Alfred Harker, F.R.S., President,
in the Chair.

Thomas Landell-Mills, Stud.Inst.M.M., Lieut. R.E., Duke of York's Headquarters, Chelsea, S.W.; and John Watson, M.A., Bracondale, Brooklands Avenue, Cambridge, were elected Fellows of the Society.

The List of Donations to the Library was read.

Dr. Aubrey Strahan, F.R.S., Director of H.M. Geological Survey, addressing the President and Fellows, said that in 1914 a proposal was made to subscribe for a bust of Sir Archibald Geikie which would be presented to the Board of Education for preservation in the Museum of Practical Geology. Notwithstanding that war broke out shortly after the scheme was launched, the proposal was warmly supported by geologists at home and abroad, and among others by Fellows of the Society. A marble bust, executed by Prof. E. Lantéri, of the Royal College of Art, was presented to the Board on March 14th, 1916, and placed in the Museum. At the same time a replica was presented to Sir Archibald, who has since made it a gift to the University of Edinburgh, where he was the first Murchison Professor. The past and present staff of the Geological Survey and Museum, thinking that a copy of the original model of the bust would be a suitable gift to the Geological Society of London, in whose affairs Sir Archibald had taken so prominent a part, had caused a cast to be made, and Dr. Strahan, on their behalf, offered it for the acceptance of the Society.

The President, referring to Sir Archibald Geikie's long and intimate connexion with the Society, gratefully accepted the gift on behalf of the Fellows.

[1] 'The Occurrence in Kimberlite of Garnet-Pyroxene Nodules carrying Diamonds' Trans. Geol. Soc. S. Africa, vol. x (1907) pp. 65-68.

Scoresby Routledge, M.A., gave an account of Easter Island. He said that the Expedition, that he had had the honour to command, was organized with the object of carrying out a long-standing wish of various bodies interested in anthropology. This wish was that Easter Island, and other islands nearest to it, though far distant from it, should be thoroughly examined, and that all information and material thereon found should be carefully considered on the spot, or, if possible, be brought back for comparative study.

This programme necessitated a vessel being specially designed, built, and equipped for the purpose. A schooner with auxiliary motor power, the 'Mana,' of 90 tons gross register, 78 feet on the water-line, 20 feet beam, and drawing 10·5 feet aft, was accordingly completed by the end of 1912, and she sailed from Southampton in February 1913 with a company of twelve all told, of whom four formed the scientific staff. After the longest voyage ever made by a yacht under canvas, she sailed into Southampton again in June 1916, without having experienced accident to man or material.

The course taken was through the Magellan Straits, and thence through the labyrinth of Andean waterways that stretch north therefrom, and are known as the Patagonian Channels.

On reaching Juan Fernandez Island, the 'Mana' had to put back to Valparaiso because the geologist of the Expedition, the late Mr. F. L. Corry, had contracted typhoid fever on the Chilean coast. Mr. Corry never recovered sufficiently to allow him to rejoin the Expedition. Hence no formal geological report on the island could be submitted to the Meeting. It was thought best, therefore, to endeavour to convey the conditions existent on Easter Island by means of a series of panoramic and other photographs, specially taken to illustrate geological features. As these very largely consist of coast-sections, the opportunity was taken to show, and explain, other pictures that were closely associated with them. Such were the ruins of the village called Orongo, consisting of peculiar canoe-shaped houses built of imbricated slabs of shale, with the roof convex, both longitudinally and transversely, on its exterior aspect, and covered with earth. They are romantically situated on the rim of the volcano of Rano Kao, with an almost sheer drop of 900 feet into the sea, or of 600 feet into the crater-lake. At Orongo, too, are found certain large rocks, carved with the symbol of a bird-headed man, holding in his hand an egg. A cult, based on annually obtaining the first-laid egg of a certain migratory sea-bird, was thus gradually brought to light, and appears to be a unique form of worship. A brief outline only could be given of some of the knowledge obtained concerning the peculiar routine associated with seeking, and taking, the sacred egg, and of the part which it occupied in the former religious life of the island.

Proceeding along the coast, the Lecturer showed typical examples

of the great terraces, and their giant stone figures, and discussed their leading characteristics. A submarine freshwater spring, near the great image-terrace of Tongariki, and opposite certain typical lava-formed caves, gave occasion to the Lecturer to explain how had arisen the longstanding, and world-wide spread report, that man and beast on Easter Island habitually drink sea-water, in the place of fresh.

The old volcano of Rano Raraku, the centre of the former religious life of the island, was then described. A series of panoramic pictures, preceded by an accurate survey made by Lieut. R. D. Ritchie, R.N., the Cartographer of the Expedition, showed a crater-lake surrounded by a rim of tuff which rises to a height of 540 feet above the surrounding plain. The plain is undulating in surface, formed superficially of hard, dense, but nevertheless vesicular, lava, and it rests on compact non-columnar basalt. One section of this crater-wall, some 600 yards long, on both its interior and exterior aspects, was seen to be quarried right up to the highest point. On the mountain-face, both inside and out, large numbers of statues, in every state of completion, were to be seen. The largest of these measured 68 feet in length. Some of those excavated by the Expedition exhibited fine details, such as the finger-nails, in perfect condition.

In conclusion, Easter Island might be described as a plateau of basalt raised from 50 to 100 feet above the sea. Superimposed on this were numerous cones ranging up to nearly 2000 feet. The plateau was covered but sparsely with soil, and could only be crossed with difficulty in any direct line. The cones, on the other hand, were generally smooth of surface, with a good depth of soil. Nevertheless the island is practically without trees, bushes, or shrubs.

A short discussion followed, to which the Lecturer replied; and the thanks of the Fellows present were accorded to Mr. Routledge for his lecture.

A large series of lantern-slides and specimens of the rock of which the stone-images of Easter Island were made, were exhibited by Scoresby Routledge, M.A.

J. B. Scrivenor, M.A., F.G.S., Government Geologist to the Federated Malay States, exhibited a manuscript geological map of the Malay States. This map, which he presented to the Society, was prepared by himself from all sources, and represented all that was known of the geology of the region at the end of the year 1916.

February 7th, 1917.

Dr. Alfred Harker, F.R.S., President,
in the Chair.

The List of Donations to the Library was read.

The following communications were read:—

1. 'The Trias of New Zealand.' By Charles Taylor Trechmann, M.Sc., F.G.S.

2. 'The Triassic Crinoids from New Zealand collected by Mr. C. T. Trechmann.' By Francis Arthur Bather, M.A., D.Sc., F.R.S., F.G.S.

3. 'On a Spilitic Facies of Lower Carboniferous Lava-Flows in Derbyshire.' By Henry Crunden Sargent, F.G.S.

Lantern-slides, fossils, and gutta-percha impressions of fossils from the Trias of New Zealand were exhibited by C. T. Trechmann, M.Sc., F.G.S., in illustration of his paper.

Lantern-slides, rock-specimens, and microscope-slides of rocks, illustrative of the Carboniferous lava-flows in Derbyshire, were exhibited by H. C. Sargent, F.G.S.

ANNUAL GENERAL MEETING.

February 16th, 1917.

Dr. Alfred Harker, F.R.S., President, in the Chair.

Report of the Council for 1916.

During the year under review, 34 new Fellows were elected into the Society (3 more than in 1915). Of the Fellows elected in 1916, 27 paid their Admission Fees before the end of that year, and of the Fellows who had been elected in the previous year, 7 paid their Admission Fees in 1916, making the total accession of new Fellows during the past year amount to 34 (3 more than in 1915).

Allowing for the loss of 66 Fellows (15 resigned, 29 deceased, and 22 removed from the List, under Bye-Law Sect. VI, Art. 5), it will be seen that there is a decrease of 32 in the number of Fellows (as compared with a decrease of 59 in 1915, and an increase of 11 in 1914).

The Total Number of Fellows is, therefore, at present 1231, made up as follows:—Compounders 226 (7 less than in 1915); Contributing Fellows 990 (25 less than in 1915); and Non-Contributing Fellows 15 (the same as in 1915).

Turning now to the Lists of Foreign Members and Foreign Correspondents, the Council has to regret the loss during the past year of Prof. J. Gosselet, M. M. F. Mourlon, and Count H. zu Solms-Laubach. It will be remembered that, in the List of Foreign Members at the end of 1915, there were two vacancies, and five in that of Foreign Correspondents; and, as no elections were held to make up the numbers during the past year, there are, at present, four vacancies in the List of Foreign Members and six vacancies in that of Foreign Correspondents.

The Society has to record, with deep regret, the loss during the year of its Treasurer, Mr. Bedford McNeill, who died on September 18th, 1916, after holding office for 4 years. Mr. McNeill had also served on the Council for 11 years, and the vacancy caused by his decease was filled on November 22nd by the election of Dr. James Vincent Elsden as Treasurer and as a Member of the Council.

With regard to the Income and Expenditure of the Society during 1916, the figures set forth in detail in the Balance-Sheet may be summarized as follows:—The actual Receipts (excluding the Balance of £635 13*s.* 4*d.* brought forward from the previous year) amounted to £2668 3*s.* 1*d.*, being £109 9*s.* 1*d.* more than the estimated Income.

On the other hand, the Expenditure during the same year

amounted to £2627 4*s*. 0*d*., being £68 10*s*. 0*d*. more than the estimated Expenditure, and the year closed with a Balance in hand of £676 12*s*. 5*d*.

On account of the special need at the present time of safeguarding the Society's Archives, a strong-room has been built for their reception; and the existence of a particularly suitable site in the basement of the Apartments permitted of this being carried out at a comparatively low cost.

In response to the Treasury's appeal to holders of Canadian Securities, the Society's holding of £2000 Canadian 3½ per cent. Registered Stock, in which the Sorby and Hudleston Bequests were invested, was deposited on loan with H.M. Government (under Treasury Scheme B).

With regard to the publications of the Society, the Council has to announce the completion of Vol. LXXI of the Quarterly Journal (1915).

In accordance with the provisions of the modification of Bye-Law Section VI, Art. 4, sanctioned at the Special General Meeting of March 10th, 1915, the Council has, on the motion of the Treasurer, remitted the contributions of 31 Fellows serving with His Majesty's Forces.

During the past year the Apartments of the Society have been used for General and for Council Meetings by the Mineralogical Society, the Palæontographical Society, the Ray Society, the Geological Physics Society, the Institution of Mining Engineers, the Institution of Mining & Metallurgy, the Institution of Water Engineers, the Institution of Municipal & County Engineers, the Society of Engineers, and the South-Eastern Union of Scientific Societies.

At the request of the Advisory Council for Scientific & Industrial Research, a Committee was formed to assist the Advisory Council on matters of geological importance that might arise from time to time. A Committee has also been formed to co-operate with the Conjoint Board of Scientific Societies, and Dr. A. Strahan and Prof. W. G. Fearnsides have been nominated as the Society's representatives on this Board.

The fourteenth Award from the Daniel Pidgeon Trust Fund was made on April 5th, 1916, to John Kaye Charlesworth, M.Sc., Ph.D., who proposed to conduct researches in connexion with the Glaciation of Donegal.

The following Awards of Medals and Funds have also been made:—

The Wollaston Medal is awarded to Prof. Antoine François Alfred Lacroix, in recognition of his 'researches concerning the Mineral Structure of the Earth,' especially in connexion with the Mineralogy and Petrology of France and her Colonies.

The Murchison Medal, together with a sum of Ten Guineas from the Murchison Geological Fund, is awarded to Dr. George Frederic Matthew, as an acknowledgment of his valuable work on the Stratigraphy and Palæontology of the Lower Palæozoic Rocks of North America.

The Lyell Medal, together with a sum of Twenty Pounds, is awarded to Dr. Wheelton Hind, as an acknowledgment of the value of his contributions to the Geology of the Carboniferous Rocks of Britain, and of his researches on the Palæozoic Lamellibranchia.

The Bigsby Medal is awarded to Mr. Robert George Carruthers, as a mark of appreciation of his work on the Carboniferous Anthozoa and of his contributions to Scottish Geology, and to stimulate him to further research.

The Balance of the proceeds of the Wollaston Donation Fund is awarded to Dr. Percy George Hamnall Boswell, in recognition of his investigations on the Tertiary and Quaternary Deposits of East Anglia, and on the Petrology of the Sedimentary Rocks.

The Balance of the proceeds of the Murchison Geological Fund is awarded to Dr. William Mackie, as an acknowledgment of his valuable work on the Sedimentary and Igneous Rocks of Scotland, especially in connexion with his researches on the Petrology and Palæontology of the Old Red Sandstone of Elgin.

A Moiety of the Balance of the proceeds of the Lyell Geological Fund is awarded to Dr. Arthur Hubert Cox, in recognition of the value of his contributions to the Stratigraphy of the Lower Palæozoic Rocks of South and Central Wales.

The second Moiety of the Balance of the proceeds of the Lyell Geological Fund is awarded to Mr. Tressilian Charles Nicholas, as an acknowledgment of his work on the Stratigraphy and Palæontology of the Lower Palæozoic Rocks of North Wales.

The Balance of the proceeds of the Barlow-Jameson Fund is awarded to Mr. Henry Dewey, in recognition of his contributions to the Geology of the South-West of England and of his researches in connexion with Quaternary Deposits.

Report of the Library Committee for 1916.

Much progress in the work of the Library has been made during the year, and the number and importance of the accessions from the usual sources are approximately the same as those of last year. The binding of serials has been kept well in hand, and 115 separate sheets of maps have been mounted.

A notable addition was made during the recess in the form of numerous volumes and pamphlets presented by Mr. R. D. Oldham, F.R.S. The series obtained from Mr. Oldham's Library is particularly rich in seismological literature, and three serials in this branch are new to the Society's Library; they are the Publications of the Japanese Earthquake Committee in Foreign Languages, the Bulletins of the Imperial Earthquake Investigation Committee, and the Bollettino della Società Sismologica Italiana. Two other serials were presented—the Annual Reports of the Cape of Good Hope Geological Commission from its commencement until 1911, and a complete set of the publications of the Société de Spéléologie, Paris; the former is a valuable addition on account of its rarity,

and the latter on account of its being the only complete set now in a London Library. In all 91 Volumes of serials have been added.

Thirty-nine Volumes of separately-published works were also chosen from Mr. Oldham's Library; most of them were new to the Society's collection, but certain duplicates were selected on account of their use for purposes of circulation.

A series of pamphlets, reports and extracts (numbering altogether 156 works) forms an important part of this new addition. Indian geology is represented in this section by 45 publications, several rare reports being included. There are 47 papers on Earthquakes, 32 on Permian Glaciation, 9 on Petrology, and 7 on Palæobotany, the remaining 16 being of a miscellaneous character. Included also in Mr. Oldham's donation are seismograms of the North Pacific and South American Earthquake of August 16th, 1906 (published by the International Seismological Association) and an Album of Photographs of the Gohna Landslip of 1894.

Donations from other sources number 18 Volumes of separately-published works, 184 Pamphlets, and 2 detached Parts of works, also 124 Volumes and 386 detached Parts of serial publications, 44 Volumes and 123 detached Parts of the publications of Geological Surveys and other public bodies, and 8 Volumes of weekly periodicals.

The total number of accessions by Donation amounts, therefore, to 324 Volumes, 340 Pamphlets, and 509 detached Parts.

Among the books and pamphlets mentioned in the foregoing paragraph, especial attention may be drawn to the following works:—'The Subantarctic Islands of New Zealand: Reports on the Geo-Physics, Geology, &c.,' 2 vols., edited by C. Chilton (Philosophical Institute of Canterbury, New Zealand), 1909; 'Fossil Vertebrates in the American Museum of Natural History —Department of Vertebrate Palæontology,' vol. iv (1915) and vol. v (1916), by H. F. Osborn and others; 'The Geology of the English Lake District,' by J. E. Marr, 1916; 'The Topography & Geology of West Central Sinai,' by John Ball (Ministry of Finance, Survey Department of Egypt), 1916; 'A Bibliography of Yorkshire Geology,' by T. Sheppard (C. Fox-Strangways Memorial Volume—Proc. Yorks. Geol. Soc. vol. xviii, 1915); 'Papers from the Geological Department, Glasgow University,' vol. ii (1915), 1916; the third edition of the 'Data of Geochemistry,' by F. W. Clarke (Bulletin of the United States Geological Survey, No. 616, 1916); Ricerche Idrogeologiche, Botaniche, &c., fatte nella Somalia Italiana Meridionale, 1913' (Missione Stephanini-Paoli — Relazioni & Monografie Agraria-Coloniali, No. 7, 1916); 6 parts of the 'Mémoires du Service Géologique de l'Indochine,' dealing with the stratigraphy and palæontology of that region; and, among the publications of the Geological Survey of England and Wales, the volume on the Thicknesses of Strata and five volumes of Special Reports on the Mineral Resources of Great Britain.

An extensive series of works has also been received from the

United States Geological Survey; and the Geological Survey of Canada has presented a number of memoirs of economic importance.

Numerous Colonial Office Reports have been presented through the kindness of Mr. J. F. N. Green, and it has thus been found possible to complete certain sets of these publications in the Society's Library. A series of reports relating to the Mineral Survey of Ceylon has also been presented by Dr. A. K. Coomaraswamy.

A decrease in the number of new Maps received is again to be noted; but this year 12 sheets have been received from the Geological Survey of Japan, 2 from that of New South Wales, 2 from that of Scotland, and one each from British Guiana, Mysore, Norway, Tasmania, and Tennessee.

The Donors during the preceding year included 99 Government Departments and other Public Bodies, 103 Societies and Editors of Periodicals, and 113 Personal Donors.

The Purchases included 38 Volumes and 7 detached Parts of separately published works, and 6 Volumes and 34 detached Parts of works published serially.

The Expenditure incurred in connexion with the Library during the year under review was as follows:—

	£	s.	d.
Books and Periodicals	71	7	3
Binding and Map-mounting	65	8	11
Catalogue Cabinets	37	16	0
Catalogue Cards	11	3	8
Total	£185	10	10

Work on the cataloguing and indexing of the accessions of 1913 has been well advanced, and good progress has been made with No. 20 of the 'Record of Geological Literature.'

With reference to the Card-Catalogue of the Library, a slip was issued with No. 283 of the Quarterly Journal (September 1916), setting forth the progress of Mr. Sherborn's work. When the task of editing the existing material has been accomplished, the Catalogue will be practically complete from the year 1800 to 1912; while it contains a large number of entries relating to previous years. The Catalogue includes over a million entries to which reference can be made, and is now contained in 540 drawers of cards under one alphabetical arrangement of authors, subjects, and localities. The recent publication by the Cambridge University Press of the fifteenth volume of the Royal Society's Catalogue of Scientific Literature will entail many further additions to the Card-Catalogue. This new volume ranges from FITTING to HYSLOP, and Mr. Sherborn is now engaged on the selection of the geological papers, the transference to cards, and the indexing and incorporation of the titles, etc. of those papers.

The appended Lists contain the Names of Government Departments, Public Bodies, Societies, Editors, and Personal Donors, from whom Donations to the Library have been received during the year under review:—

I. Government Departments and other Public Bodies.

American Museum of Natural History. New York.
Australia (S.), etc. *See* South Australia, *etc.*
Bergens Museum. Bergen.
Birmingham, University of.
British Columbia.—Department of Mines. Victoria (B.C.).
British Guiana.—Department of Mines. Georgetown.
Buenos Aires.—Museo Nacional de Buenos Aires.
California.—Academy of Sciences. San Francisco.
——, University of. Berkeley (Cal.).
Camborne.—Mining School.
Cambridge (Mass.).—Museum of Comparative Zoology in Harvard College.
Canada.—Department of Mines. Ottawa.
——, High Commissioner for. London.
Cape of Good Hope.—South African Museum. Cape Town.
Chicago.—'Field' Columbian Museum.
Connecticut.—State Geological & Natural History Survey. Hartford (Conn.).
Córdoba (Argentine Republic).—Academía Nacional de Ciencias.
Denmark.—Geologiske Undersögelse. Copenhagen.
——. Kongelige Danske Videnskabernes Selskab. Copenhagen.
Dublin.—Royal Irish Academy.
Egypt.—Department of Public Works (Survey Department). Cairo.
Great Britain.—British Museum (Natural History). London.
——. Colonial Office. London.
——. Geological Survey. London.
——. Home Office. London.
Holland.—Rijksopsporing van Delfstoffen. The Hague.
Hull.—Municipal Museum.
Illinois State Geological Survey. Urbana (Ill.).
India.—Geological Survey. Calcutta.
——. Surveyor-General's Office. Calcutta.
Iowa Geological Survey. Des Moines (Iowa).
Ireland.—Department of Agriculture & Technical Instruction. Dublin.
Italy.—Reale Comitato Geologico. Rome.
Japan.—Earthquake-Investigation Committee. Tokyo.
——. Geological Survey. Tokyo.
Kingston (Canada).—Queen's College.
Leeds, University of.
London.—City of London College.
——. Imperial College of Science & Technology.
——. Imperial Institute.
——. Metropolitan Water Board.
——. Royal College of Surgeons.
——. University College.
Madrid.—Real Academía de Ciencias Exactas, Físicas & Naturales.
Melbourne (Victoria).—National Museum.
Mexico.—Instituto Geológico. Mexico City.
Milan.—Reale Istituto Lombardo di Scienze & Lettere.
New Jersey.—Geological Survey. Trentham (N.J.).
New South Wales, Agent-General for. London.
——. Department of Mines & Agriculture. Sydney.
——. Geological Survey. Sydney.
New York State Museum. Albany (N.Y.).
New Zealand.—Department of Mines. Wellington.
——. Geological Survey. Wellington.
Norway.—Norges Geologiske Undersökelse. Christiania.
Nova Scotia.—Department of Mines. Halifax.
Ohio Geological Survey. Columbus (Ohio).
Oklahoma Geological Survey. Norman (Okla.).

Ontario.—Bureau of Mines. Toronto.
Padua.—Reale Accademia di Scienze, Lettere & Arti.
——, Royal University of.
Paris.—Académie des Sciences.
Peru.—Ministerio de Fomento. Lima.
Philippine Is.—Department of the Interior: Bureau of Science. Manila.
Pisa, Royal University of.
Portugal.—Commissão dos Trabalhos Geologicos. Lisbon.
Queensland, Agent-General for. London.
——. Department of Mines. Brisbane.
——. Geological Survey. Brisbane.
Redruth.—School of Mines.
Rio de Janeiro.—Museu Nacional.
Rome.—Reale Accademia dei Lincei.
Russia.—Comité Géologique. Petrograd.
——. Musée Géologique Pierre le Grand. Petrograd.
——. Section Géologique du Cabinet de S.M. l'Empereur. Petrograd.
São Paulo (Brazil).—Commissão Geographica & Geologica. São Paulo City.
——. Secretaria da Agricultura, Commercio & Obras Publicas. São Paulo City.
Sendai (Japan).—Tohoku Imperial University.
South Africa, Union of.—Department of Mines. Pretoria
South Australia, Agent-General for. London.
——. Department of Mines. Adelaide.
——. Geological Survey. Adelaide.
Stockholm.—Kongliga Svenska Vetenskaps Akademi.
Sweden.—Sveriges Geologiska Undersökning. Stockholm.
Switzerland.—Geologische Kommission der Schweiz. Berne.
Tasmania.—Secretary for Mines. Hobart.
Tokyo.—College of Science (Imperial University).
Turin.—Reale Accademia delle Scienze.
Union of South Africa. *See* South Africa.
United States.—Department of Agriculture. Washington (D.C.).
——. Geological Survey. Washington (D.C.).
——. National Museum. Washington (D.C.).
Upsala, Royal University of.
Victoria (Austral.), Agent-General for. London.
—— (——). Department of Mines. Melbourne.
—— (——). Geological Survey. Melbourne.
Washington (D.C.).—Smithsonian Institution.
Washington, State of (U.S.A.).—Geological Survey. Olympic (Wash.).
Western Australia, Agent-General for. London.
——. Department of Mines. Perth.
——. Geological Survey. Perth.

II. Societies and Editors.

Adelaide.—Royal Society of South Australia.
Basel.—Naturforschende Gesellschaft.
Bergen.—'Naturen.'
Berne.—Schweizerische Naturforschende Gesellschaft.
Boston (Mass.).—American Academy of Arts & Sciences.
Bristol Naturalists' Society.
Buenos Aires.—Sociedad Científica Argentina.
Calcutta.—Asiatic Society of Bengal.
Cambridge Philosophical Society.
Cape Town.—Royal Society of South Africa.
——. South African Association for the Advancement of Science.
Cardiff.—South Wales Institute of Engineers.
Chicago.—'Journal of Geology.'
Christiania.—'Nyt Magazin for Naturvidenskaberne.'
Croydon Natural History & Scientific Society.
Dorchester.—Dorset Natural History & Antiquarian Field-Club.
Dorpat (Jurjew).—Naturforschende Gesellschaft.
Edinburgh.—Geological Society.
——. Royal Scottish Geographical Society.
——. Royal Society.

Ekaterinburg.—Société Ouralienne d'Amateurs des Sciences Naturelles
Falmouth.—Royal Cornwall Polytechnic Society.
Geneva.—Société de Physique & d'Histoire Naturelle.
Glasgow.—Geological Society.
Gloucester.—Cotteswold Naturalists' Field-Club.
Hereford.—Woolhope Naturalists' Field-Club.
Hertford.—Hertfordshire Natural History Society.
Hull Geological Society.
Johannesburg.—Geological Society of South Africa.
Kiev.—Société des Naturalistes.
Lancaster (Pa.).—'Economic Geology.'
Leeds.—Yorkshire Geological Society.
Leicester Literary & Philosophical Society.
Lima.—'Revista de Ciencias.'
Lisbon.—Sociedade de Geographia.
——. Société Portugaise des Sciences Naturelles.
Liverpool Geological Society.
——. Literary & Philosophical Society.
London.—British Association for the Advancement of Science.
——. Chemical Society.
——. 'The Chemical News.'
——. 'The Colliery Guardian.'
——. 'The Geological Magazine.'
——. Geologists' Association.
——. Institution of Civil Engineers.
——. Institution of Mining Engineers.
——. Institution of Mining & Metallurgy.
——. Institution of Water Engineers.
——. Iron & Steel Institute.
——. Linnean Society.
——. 'The London, Edinburgh, & Dublin Philosophical Magazine.'
——. Mineralogical Society.
——. 'Nature.'
——. Palæontographical Society.
——. Prehistoric Society of East Anglia.
——. 'The Quarry.'
——. Royal Geographical Society.
——. Royal Institution.
——. Royal Meteorological Society.
——. Royal Microscopical Society.
——. Royal Photographic Society.
——. Royal Society.
——. Royal Society of Arts.
——. 'The South-Eastern Naturalist' (S.E. Union of Scientific Societies).
——. Victoria Institute.
——. 'Water.'
——. Zoological Society.
Manchester Geological & Mining Society.
——. Literary & Philosophical Society.
Melbourne (Victoria).—Australasian Institute of Mining Engineers.
——. Royal Society of Victoria.
——. 'The Victorian Naturalist.'
Mexico.—Sociedad Científica 'Antonio Alzate.'
Moscow.—Société Impériale des Naturalistes.
Newcastle-upon-Tyne.—North of England Institute of Mining & Mechanical Engineers.
——. University of Durham Philosophical Society.
New Haven (Conn.).—Academy of Arts & Sciences.
——. 'The American Journal of Science.'
New York.—Academy of Sciences.
——. American Institute of Mining Engineers.
——. 'Science.'
Northampton.—Northamptonshire Natural History Society.
Oporto.—Academia Polytecnica. [Coimbra.]
Ottawa.—Royal Society of Canada.
Perth.—Perthshire Society of Natural Science.
Philadelphia.—Academy of Natural Sciences.

Philadelphia.—American Philosophical Society.
Plymouth.—Devonshire Association for the Advancement of Science.
Rochester (N.Y.).—Academy of Science.
——. Geological Society of America.
Rome.—Società Geologica Italiana.
Rugby School Natural History Society.
Stockholm.—Geologiska Förening.
Stratford.—Essex Field-Club.
Sydney (N.S.W.).—Linnean Society of New South Wales.
——. Royal Society of New South Wales.
Toronto.—Canadian Institute.
Truro.—Royal Institution of Cornwall.
Washington (D.C.).—Academy of Sciences.
——. Philosophical Society.
Wellington (N.Z.).—New Zealand Institute.
Worcester.—Worcestershire Naturalists' Club.
York.—Yorkshire Philosophical Society.

III. Personal Donors.

Abbott, G.
Allen, H. A.
Ameghino, C.
Andrews, E. C.

Ball, J.
Barrell, J.
Batchelor, E.
Becker, G. F.
Bonney, T. G.
Boswell, P. G. H.
Bowen, N. L.

Cate, D. H. S. Blaupot ten-.
Chapman, F.
Chirvinski, P. N.
Choffat, P.
Cole, G. A. J.
Collins, J. H.
Coomaraswamy, A. K.
Cope, Mrs. T. H.
Craig, E. H. C.
Crick, G. C.
Cumings, E. R.

Dall, W. H.
Daly, R. A.
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Foye, W. G.

Gadeceau, E.
Galloway, J. J.
Geikie, Sir Archibald.
Green, J. F. N.
Gregorio, A. de.
Gregory, J. W.
Grosset, A.
Gurley, R. R.

Heim, Albert.
Heim, Arnold.
Henderson, J. A. L.
Holst, N. O.
Hopkinson, J.
Horne, J.
Hughes, T. McK.
Hume, W. F.

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Jackson, J. W.
Johnston, J.
Jones, W. R.

Knight, C. W.

Leach, A. L.
Leucewicz, S.
Lœwinson-Lessing, F.
Lomax, J.
Lugeon, M.
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Newton, R. B.
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Percival, F. G.
Pickering, A. J.
Preller, C. S. Du R.
Purington, C. W.

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Reusch, H.
Richards, H. C.

Sabot, R. C.
Sauvage, H. E.
Sawyer, A. R.
Schardt, H.
Schuchert, C.
Schwarz, E. H. L.
Sheppard, T.
Sherborn, C. D.
Smith, B.
Smith, R. A.
Smith, S.
Sosman, R. B.
Stebbing, W. P. D.
Stevenson, J. J.
Stobbs, J. T.
Stoyanov, A.
Strahan, A.

Thompson, B.
Titanovich, M.
Tse Tsan Tai.
Tyrrell, G. W.
Tyrrell, J. B.

Vasiliev, V. T.
Vaughan, T. W.
Veatch, A. C.

Washington, H. S.
Wherry, E. T.
Whitaker, W.
Wills, L. J.
Woodward, H.
Wray, D. A.
Wright, F. E.

Comparative Statement of the Number of the Society at the Close of the Years 1915 and 1916.

	Dec. 31st, 1915.		Dec. 31st, 1916.
Compounders	233	....	223
Contributing Fellows	1009	....	990
Non-Contributing Fellows	15	....	15
	1257		1228
Foreign Members	37	....	36
Foreign Correspondents	39	....	38
	1333		1302

Comparative Statement, explanatory of the Alterations in the Number of Fellows, Foreign Members, and Foreign Correspondents at the close of the Years 1915 and 1916.

Number of Compounders, Contributing, and Non-Contributing Fellows, December 31st, 1915 ...		1257
Add Fellows elected during the former year and paid in 1916		7
Add Fellows elected and paid in 1916		27
Add Fellows reinstated after payment of arrears.		3
		1294
Deduct Compounders deceased	10	
Contributing Fellows deceased	19	
Contributing Fellows resigned	15	
Contributing Fellows removed	22	
	—	66
		1228
Number of Foreign Members and Foreign Correspondents, December 31st, 1915	76	
Deduct Foreign Member deceased	1	
Deduct Foreign Correspondent deceased	1	
	74	
	—	74
		1302

Deceased Fellows.

Compounders (10).

Barnett, A. K. [elected 1875.]
Clough, C. T. [el. 1875.]
Derby, O. H. [el. 1884.]
Deverell, L. C. [el. 1901.]
Don, A. W. R. [el. 1912.]
Meade, T. de Courcy [el. 1891.]
Peyton, J. E. H. [el. 1871.]
Reid, Clement [el. 1875.]
Ross, W. J. C. [el. 1882.]
Stone, Sir John B. [el. 1864.]

Resident and other Contributing Fellows (19).

Allen, G. A. [elected 1904.]
Collins, J. H. [el. 1869.]
Croom-Johnson, A. [el. 1911.]
Dunlop, A. [el. 1874.]
Dawson, C. [el. 1885.]
Fairley, W. [el. 1887.]
Florence, H. L. [el. 1872.]
Fowler, G. H. [el. 1904.]
Hawtrey, R. [el. 1912.]
Holiday, F. A. [el. 1910.]
Judd, J. W. [el. 1865.]
Koch, W. E. [el. 1869.]
Lewer, R. R. [el. 1911.]
McNeill, B. [el. 1888.]
Power, E. J. [el. 1898.]
Simpson, J. C. [el. 1906.]
Swann, J. S. [el. 1865.]
Wardell, S. C. [el. 1880.]
Woodall, Sir Corbet [el. 1884.]

Fellows Resigned (15).

André, G. G.
Banbery, E. C.
Broad, W.
Butler, G. G.
Childe, H. S.
Coleman, C. J.
De Muller, W. J. E.
Gasking, S.
Hay, J. D.
Henderson, J. M'C.
Powney, W. E. F.
Rolfe, W.
Szlumper, Sir James W.
Walker, W. P.
Watermeyer, T. H.

FELLOWS REMOVED (22).

Binet, E. P.
Briggs, H.
Crankshaw, J.
Croston, J. W.
Daniel, P. F.
Davies, J.
Davies, W. H.
Eastaugh, F. A.
Hosking, J. H.
Jorissen, E.
Krausé, H. L.
Miller, F. R. L.
Perkes, S.
Poole, W.
Preston, F. M.
Prouse, O. M.
Rawlins, C. C.
Temby, E. T.
Zeller, C. van.
[+3 reinstated.]

FOREIGN MEMBER DECEASED.

Prof. Jules Gosselet.

FOREIGN CORRESPONDENT DECEASED.

M. Michel F. Mourlon.

After the Reports had been read, it was resolved :—

That they be received and entered on the Minutes of the Meeting, and that such parts of them as the Council shall think fit be printed and circulated among the Fellows.

It was afterwards resolved :—

That the thanks of the Society be given to Sir Thomas Holland and the Rev. H. H. Winwood, retiring from the office of Vice-President and also from the Council, and to the other retiring members of the Council: Mr. H. Bury, Prof. W. G. Fearnsides, and Mr. W. Whitaker.

After the Balloting-Glasses had been closed, and the Lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected as the Officers and Council for the ensuing year :—

OFFICERS AND COUNCIL.—1917.

PRESIDENT.

Alfred Harker, M.A., LL.D., F.R.S.

VICE-PRESIDENTS.

R. Mountford Deeley, M.Inst.C.E.
Edwin Tulley Newton, F.R.S.
Prof. William Johnson Sollas, M.A., LL.D., Sc.D., F.R.S.
Arthur Smith Woodward, LL.D., F.R.S., F.L.S.

SECRETARIES.

Herbert Henry Thomas, M.A., Sc.D.
Herbert Lapworth, D.Sc., M.Inst.C.E.

FOREIGN SECRETARY.

Sir Archibald Geikie, O.M., K.C.B., D.C.L., LL.D., Sc.D., F.R.S.

TREASURER.

James Vincent Elsden, D.Sc.

COUNCIL.

Charles William Andrews, D.Sc., F.R.S.
Prof. John Cadman, C.M.G., D.Sc.
Prof. Charles Gilbert Cullis, D.Sc.
Arthur Morley Davies, D.Sc.
R. Mountford Deeley, M.Inst.C.E.
Prof. Edmund Johnston Garwood, M.A., Sc.D., F.R.S.
Sir Archibald Geikie, O.M., K.C.B., D.C.L., LL.D., Sc.D., F.R.S.
Walcot Gibson, D.Sc.
Alfred Harker, M.A., LL.D., F.R.S.
Finlay Lorimer Kitchin, M.A., Ph.D.
George William Lamplugh, F.R.S.
Herbert Lapworth, D.Sc., M.Inst. C.E.
John Edward Marr, Sc.D., F.R.S.
Edwin Tulley Newton, F.R.S.
Richard Dixon Oldham, F.R.S.
Robert Heron Rastall, M.A.
Prof. Thomas Franklin Sibly, D.Sc.
Prof. William Johnson Sollas, Sc.D., LL.D., F.R.S.
Sir Jethro J. Harris Teall, M.A., D.Sc., LL.D., F.R.S.
Herbert Henry Thomas, M.A., Sc.D.
Samuel Hazzledine Warren.
Arthur Smith Woodward, LL.D., F.R.S., F.L.S.

LIST OF

THE FOREIGN MEMBERS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1916.

Date of Election.

1884. Commendatore Prof. Giovanni Capellini, *Bologna.*
1886. Prof. Gustav Tschermak, *Vienna.*
1891. Prof. Charles Barrois, *Lille.*
1893. Prof. Waldemar Christofer Brögger, *Christiania.*
1893. Prof. Alfred Gabriel Nathorst, *Stockholm.*
1894. Prof. Edward Salisbury Dana, *New Haven, Conn.* (*U.S.A.*).
1895. Dr. Grove Karl Gilbert, *Washington, D.C.* (*U.S.A.*).
1896. Prof. Albert Heim, *Zürich.*
1897. Dr. Hans Reusch, *Christiania.*
1898. Dr. Charles Doolittle Walcott, *Washington, D.C.* (*U.S.A.*).
1899. Prof. Emanuel Kayser, *Marburg.*
1899. M. Ernest Van den Broeck, *Brussels.*
1900. M. Gustave F. Dollfus, *Paris.*
1900. Prof. Paul von Groth, *Munich.*
1900. Dr. Sven Leonhard Törnquist, *Lund.*
1901. M. Alexander Petrovich Karpinsky, *Petrograd.*
1901. Prof. Antoine François Alfred Lacroix, *Paris.*
1903. Prof. Albrecht Penck, *Berlin.*
1903. Prof. Anton Koch, *Budapest.*
1904. Prof. Joseph Paxson Iddings, *Brinklow, Maryland* (*U.S.A.*).
1904. Prof. Henry Fairfield Osborn, *New York* (*U.S.A.*).
1905. Prof. Louis Dollo, *Brussels.*
1905. Prof. August Rothpletz, *Munich.*
1907. Hofrath Dr. Emil Ernst August Tietze, *Vienna.*
1907. Commendatore Prof. Arturo Issel, *Genoa.*
1908. Prof. Bundjirô Kôtô, *Tokyo.*
1909. Prof. Johan H. L. Vogt, *Christiania.*
1911. Prof. Baron Gerard Jakob de Geer, *Stockholm.*
1911. M. Emmanuel de Margerie, *Paris.*
1912. Prof. Marcellin Boule, *Paris.*
1913. Prof. Johannes Walther, *Halle an der Saale.*
1914. Prof. Friedrich Johann Becke, *Vienna.*
1914. Prof. Thomas Chrowder Chamberlin, *Chicago, Ill.* (*U.S.A.*).
1914. Prof. Franz Julius Lœwinson-Lessing, *Petrograd.*
1914. Prof. Alexis Petrovich Pavlow, *Moscow.*
1914. Prof. William Berryman Scott, *Princeton* (*New Jersey*).

LIST OF

THE FOREIGN CORRESPONDENTS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1916.

Date of Election.

1879. Dr. H. Émile Sauvage, *Boulogne-sur-Mer*. (*Deceased*.)
1889. Dr. Rogier Diederik Marius Verbeek, *The Hague*.
1890. Geheimer Bergrath Prof. Adolph von Kœnen, *Göttingen*.
1892. Prof. Johann Lehmann, *Weimar*.
1894. Dr. Francisco P. Moreno, *La Plata*.
1898. Dr. W. H. Dall, *Washington, D.C.* (*U.S.A.*).
1899. Dr. Gerhard Holm, *Stockholm*.
1899. Prof. Theodor Liebisch, *Berlin*.
1900. Prof. Federico Sacco, *Turin*.
1902. Dr. Thorvaldr Thoroddsen, *Copenhagen*.
1902. Prof. Samuel Wendell Williston, *Chicago, Ill.* (*U.S.A.*).
1904. Dr. William Bullock Clark, *Baltimore* (*U.S.A.*). (*Deceased*.)
1904. Dr. Erich Dagobert von Drygalski, *Charlottenburg*.
1904. Prof. Giuseppe de Lorenzo, *Naples*.
1904. The Hon. Frank Springer, *East Las Vegas, New Mexico* (*U.S.A.*)
1904. Dr. Henry Stephens Washington, *Washington, D.C.* (*U.S.A.*).
1906. Prof. John M. Clarke, *Albany, N.Y.* (*U.S.A.*).
1906. Prof. William Morris Davis, *Cambridge, Mass.* (*U.S.A.*).
1906. Dr. Jakob Johannes Sederholm, *Helsingfors*.
1908. Prof. Hans Schardt, *Zürich*.
1909. Dr. Daniel de Cortázar, *Madrid*.
1909. Prof. Maurice Lugeon, *Lausanne*.
1911. Prof. Arvid Gustaf Högbom, *Upsala*.
1911. Prof. Charles Depéret, *Lyons*.
1912. Dr. Frank Wigglesworth Clarke, *Washington, D.C.* (*U.S.A.*)
1912. Dr. Whitman Cross, *Washington, D.C.* (*U.S.A.*).
1912. Baron Ferencz Nopcsa, *Temesmegye* (*Hungary*).
1912. Prof. Karl Diener, *Vienna*.
1912. Prof. Fusakichi Omori, *Tokyo*.
1912. Prof. Ernst Weinschenk, *Munich*.
1913. Dr. Émile Haug, *Paris*.
1913. Dr. Per Johan Holmquist, *Stockholm*.
1914. Dr. Paul Choffat, *Lisbon*.
1914. Dr. Charles Richard Van Hise, *Madison, Wisconsin* (*U.S.A.*).

AWARDS OF THE WOLLASTON MEDAL

UNDER THE CONDITIONS OF THE 'DONATION FUND'

ESTABLISHED BY

WILLIAM HYDE WOLLASTON, M.D., F.R.S., F.G.S., ETC.

'To promote researches concerning the mineral structure of the Earth, and to enable the Council of the Geological Society to reward those individuals of any country by whom such researches may hereafter be made,'—'such individual not being a Member of the Council.'

1831. Mr. William Smith.
1835. Dr. Gideon A. Mantell.
1836. M. Louis Agassiz.
1837. { Capt. T. P. Cautley. Dr. Hugh Falconer.
1838. Sir Richard Owen.
1839. Prof. C. G. Ehrenberg.
1840. Prof. A. H. Dumont.
1841. M. Adolphe T. Brongniart.
1842. Baron Leopold von Buch.
1843. { M. Élie de Beaumont. M. P. A. Dufrénoy.
1844. The Rev. W. D. Conybeare.
1845. Prof. John Phillips.
1846. Mr. William Lonsdale.
1847. Dr. Ami Boué.
1848. The Very Rev. W. Buckland.
1849. Sir Joseph Prestwich.
1850. Mr. William Hopkins.
1851. The Rev. Prof. A. Sedgwick.
1852. Dr. W. H. Fitton.
1853. { M. le Vicomte A. d'Archiac. M. E. de Verneuil.
1854. Sir Richard Griffith.
1855. Sir Henry De la Beche.
1856. Sir William Logan.
1857. M. Joachim Barrande.
1858. { Herr Hermann von Meyer. Prof. James Hall.
1859. Mr. Charles Darwin.
1860. Mr. Searles V. Wood.
1861. Prof. Dr. H. G. Bronn.
1862. Mr. R. A. C. Godwin-Austen.
1863. Prof. Gustav Bischof.
1864. Sir Roderick Murchison.
1865. Dr. Thomas Davidson.
1866. Sir Charles Lyell.
1867. Mr. G. Poulett Scrope.
1868. Prof. Carl F. Naumann.
1869. Dr. Henry C. Sorby.
1870. Prof. G. P. Deshayes.
1871. Sir Andrew Ramsay.
1872. Prof. James D. Dana.
1873. Sir P. de M. Grey Egerton.
1874. Prof. Oswald Heer.
1875. Prof. L. G. de Koninck.
1876. Prof. Thomas H. Huxley.
1877. Mr. Robert Mallet.
1878. Dr. Thomas Wright.
1879. Prof. Bernhard Studer.
1880. Prof. Auguste Daubrée.
1881. Prof. P. Martin Duncan.
1882. Dr. Franz Ritter von Hauer.
1883. Dr. William T. Blanford.
1884. Prof. Albert Jean Gaudry.
1885. Mr. George Busk.
1886. Prof. A. L. O. Descloizeaux.
1887. Mr. John Whitaker Hulke.
1888. Mr. Henry B. Medlicott.
1889. Prof. Thomas George Bonney.
1890. Prof. W. C. Williamson.
1891. Prof. John Wesley Judd.
1892. Baron F. von Richthofen.
1893. Prof. Nevil Story Maskelyne.
1894. Prof. Karl Alfred von Zittel.
1895. Sir Archibald Geikie.
1896. Prof. Eduard Suess.
1897. Mr. Wilfrid H. Hudleston.
1898. Prof. Ferdinand Zirkel.
1899. Prof. Charles Lapworth.
1900. Dr. Grove Karl Gilbert.
1901. Prof. Charles Barrois.
1902. Dr. Friedrich Schmidt.
1903. Prof. Heinrich Rosenbusch.
1904. Prof. Albert Heim.
1905. Sir Jethro J. H. Teall.
1906. Dr. Henry Woodward.
1907. Prof. William J. Sollas.
1908. Prof. Paul von Groth.
1909. Mr. Horace B. Woodward.
1910. Prof. William B. Scott.
1911. Prof. Waldemar C. Brögger.
1912. Sir Lazarus Fletcher.
1913. The Rev. Osmond Fisher.
1914. Prof. John Edward Marr.
1915. Prof. T. W. Edgeworth David.
1916. Dr. A. P. Karpinsky.
1917. Prof. A. F. A. Lacroix.

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE WOLLASTON 'DONATION FUND.'

1831. Mr. William Smith.
1833. Mr. William Lonsdale.
1834. M. Louis Agassiz.
1835. Dr. Gideon A. Mantell.
1836. Prof. G. P. Deshayes.
1838. Sir Richard Owen.
1839. Prof. C. G. Ehrenberg.
1840. Mr. J. De Carle Sowerby.
1841. Prof. Edward Forbes.
1842. Prof. John Morris.
1843. Prof. John Morris.
1844. Mr. William Lonsdale.
1845. Mr. Geddes Bain.
1846. Mr. William Lonsdale.
1847. M. Alcide d'Orbigny.
1848. { Cape of Good Hope fossils. M. Alcide d'Orbigny. }
1849. Mr. William Lonsdale.
1850. Prof. John Morris.
1851. M. Joachim Barrande.
1852. Prof. John Morris.
1853. Prof. L. G. de Koninck.
1854. Dr. Samuel P. Woodward.
1855. { Dr. G. Sandberger. Dr. F. Sandberger. }
1856. Prof. G. P. Deshayes.
1857. Dr. Samuel P. Woodward.
1858. Prof. James Hall.
1859. Mr. Charles Peach.
1860. { Prof. T. Rupert Jones. Mr. W. K. Parker. }
1861. Prof. Auguste Daubrée.
1862. Prof. Oswald Heer.
1863. Prof. Ferdinand Senft.
1864. Prof. G. P. Deshayes.
1865. Mr. J. W. Salter.
1866. Dr. Henry Woodward.
1867. Mr. W. H. Baily.
1868. M. J. Bosquet.
1869. Dr. William Carruthers.
1870. M. Marie Rouault.
1871 Mr. Robert Etheridge.
1872. Dr. James Croll.
1873. Prof. John Wesley Judd.
1874. Dr. Henri Nyst.
1875. Prof. Louis C. Miall.
1876. Prof. Giuseppe Seguenza.
1877. Mr. Robert Etheridge, jun.
1878. Prof. William J. Sollas.
1879. Mr. Samuel Allport.
1880. Mr. Thomas Davies.
1881. Dr. Ramsay H. Traquair.
1882. Dr. George Jennings Hinde.
1883. Prof. John Milne.
1884. Mr. Edwin Tulley Newton.
1885. Dr. Charles Callaway.
1886. Mr. J. Starkie Gardner.
1887. Dr. Benjamin Neeve Peach.
1888. Dr. John Horne.
1889. Dr. A. Smith Woodward.
1890. Mr. William A. E. Ussher.
1891. Mr. Richard Lydekker.
1892. Mr. Orville Adelbert Derby.
1893. Mr. John George Goodchild.
1894. Dr. Aubrey Strahan.
1895. Prof. William W. Watts.
1896. Dr. Alfred Harker.
1897. Dr. Francis Arthur Bather.
1898. Prof. Edmund J. Garwood.
1899. Prof. John B. Harrison.
1900. Dr. George Thurland Prior.
1901. Dr. Arthur Walton Rowe.
1902. Mr. Leonard James Spencer.
1903. Mr. L. L. Belinfante.
1904. Miss Ethel M. R. Wood.
1905. Dr. Henry Howe Bemrose.
1906. Dr. Finlay Lorimer Kitchin.
1907. Dr. Arthur Vaughan.
1908. Dr. Herbert Henry Thomas.
1909. Mr. Arthur J. C. Molyneux.
1910. Mr. Edward B. Bailey.
1911. Prof. Owen Thomas Jones.
1912. Mr. Charles Irving Gardiner.
1913. Mr. William Wickham King.
1914. Mr. R. Bullen Newton.
1915. Mr. Charles Bertie Wedd.
1916. Mr. William Bourke Wright.
1917. Prof. Percy G. H. Boswell.

AWARDS OF THE MURCHISON MEDAL

UNDER THE CONDITIONS OF THE

'MURCHISON GEOLOGICAL FUND,'

ESTABLISHED UNDER THE WILL OF THE LATE

SIR RODERICK IMPEY MURCHISON, Bart., F.R.S., F.G.S.

'To be applied in every consecutive year, in such manner as the Council of the Society may deem most useful in advancing Geological Science, whether by granting sums of money to travellers in pursuit of knowledge, to authors of memoirs, or to persons actually employed in any enquiries bearing upon the science of Geology, or in rewarding any such travellers, authors, or other persons, and the Medal to be given to some person to whom such Council shall grant any sum of money or recompense in respect of Geological Science.'

1873. Mr. William Davies.
1874. Dr. J. J. Bigsby.
1875. Mr. W. J. Henwood.
1876. Mr. Alfred R. C. Selwyn.
1877. The Rev. W. B. Clarke.
1878. Prof. Hanns Bruno Geinitz.
1879. Sir Frederick M'Coy.
1880. Mr. Robert Etheridge.
1881. Sir Archibald Geikie.
1882. Prof. Jules Gosselet.
1883. Prof. H. R. Gœppert.
1884. Dr. Henry Woodward.
1885. Dr. Ferdinand von Rœmer.
1886. Mr. William Whitaker.
1887. The Rev. Peter B. Brodie.
1888. Prof. J. S. Newberry.
1889. Prof. James Geikie.
1890. Prof. Edward Hull.
1891. Prof. Waldemar C. Brögger.
1892. Prof. A. H. Green.
1893. The Rev. Osmond Fisher.
1894. Mr. William T. Aveline.
1895. Prof. Gustaf Lindström.
1896. Mr. T. Mellard Reade.
1897. Mr. Horace B. Woodward.
1898. Mr. Thomas F. Jamieson.
1899. { Dr. Benjamin Neeve Peach. / Dr. John Horne.
1900. Baron A. E. Nordenskiöld.
1901. Mr. A. J. Jukes-Browne.
1902. Mr. Frederic W. Harmer.
1903. Dr. Charles Callaway.
1904. Prof. George A. Lebour.
1905. Mr. Edward John Dunn.
1906. Dr. Charles T. Clough.
1907. Dr. Alfred Harker.
1908. Prof. Albert Charles Seward.
1909. Prof. Grenville A. J. Cole.
1910. Prof. Arthur P. Coleman.
1911. Mr. Richard Hill Tiddeman.
1912. Prof. Louis Dollo.
1913. Mr. George Barrow.
1914. Mr. William A. E. Ussher.
1915. Prof. William W. Watts.
1916. Dr. Robert Kidston.
1917. Dr. George F. Matthew.

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE 'MURCHISON GEOLOGICAL FUND.'

1873. Prof. Oswald Heer.
1874. Mr. Alfred Bell.
Prof. Ralph Tate.
1875. Prof. H. Govier Seeley.
1876. Dr. James Croll.
1877. The Rev. John F. Blake.
1878. Prof. Charles Lapworth.
1879. Mr. James Walker Kirkby.
1880. Mr. Robert Etheridge.
1881. Mr. Frank Rutley.
1882. Prof. Thomas Rupert Jones.
1883. Dr. John Young.
1884. Mr. Martin Simpson.
1885. Mr. Horace B. Woodward.
1886. Mr. Clement Reid.
1887. Dr. Robert Kidston.
1888. Mr. Edward Wilson.
1889. Prof. Grenville A. J. Cole.
1890. Mr. Edward B. Wethered.
1891. The Rev. Richard Baron.
1892. Mr. Beeby Thompson.
1893. Mr. Griffith John Williams.
1894. Mr. George Barrow.
1895. Prof. Albert Charles Seward.
1896. Mr. Philip Lake.
1897. Mr. Sydney S. Buckman.
1898. Miss Jane Donald.
1899. Mr. James Bennie.
1900. Mr. A. Vaughan Jennings.
1901. Mr. Thomas S. Hall.
1902. Sir Thomas H. Holland.
1903. Mrs. Elizabeth Gray.
1904. Dr. Arthur Hutchinson.
1905. Prof. Herbert L. Bowman.
1906. Dr. Herbert Lapworth.
1907. Dr. Felix Oswald.
1908. Miss Ethel Gertrude Skeat.
1909. Dr. James Vincent Elsden.
1910. Mr. John Walker Stather.
1911. Mr. Edgar Sterling Cobbold.
1912. Dr. Arthur Morley Davies.
1913. Mr. Ernest E. L. Dixon.
1914. Mr. Frederick Nairn Haward.
1915. Mr. David Cledlyn Evans.
1916. Mr. George Walter Tyrrell.
1917. Dr. William Mackie.

AWARDS OF THE LYELL MEDAL

UNDER THE CONDITIONS OF THE

'LYELL GEOLOGICAL FUND,'

ESTABLISHED UNDER THE WILL AND CODICIL OF THE LATE

SIR CHARLES LYELL, Bart., F.R.S., F.G.S.

The Medal 'to be cast in bronze and to be given annually' (or from time to time) 'as a mark of honorary distinction and as an expression on the part of the governing body of the Society that the Medallist (who may be of any country or either sex) has deserved well of the Science,'—'not less than one third of the annual interest [of the fund] to accompany the Medal, the remaining interest to be given in one or more portions, at the discretion of the Council, for the encouragement of Geology or of any of the allied sciences by which they shall consider Geology to have been most materially advanced, either for travelling expenses or for a memoir or paper published, or in progress, and without reference to the sex or nationality of the author, or the language in which any such memoir or paper may be written.'

There is a further provision for suspending the award for one year, and in such case for the awarding of a Medal to 'each of two persons who have been jointly engaged in the same exploration in the same country, or perhaps on allied subjects in different countries, the proportion of interest always not being less to each Medal than one third of the annual interest.'

1876. Prof. John Morris.
1877. Sir James Hector.
1878. Mr. George Busk.
1879. Prof. Edmond Hébert.
1880. Sir John Evans.
1881. Sir J. William Dawson.
1882. Dr. J. Lycett.
1883. Dr. W. B. Carpenter.
1884. Dr. Joseph Leidy.
1885. Prof. H. Govier Seeley.
1886. Mr. William Pengelly.
1887. Mr. Samuel Allport.
1888. Prof. Henry A. Nicholson.
1889. Prof. W. Boyd Dawkins.
1890. Prof. Thomas Rupert Jones.
1891. Prof. T. McKenny Hughes.
1892. Mr. George H. Morton.
1893. Mr. Edwin Tulley Newton.
1894. Prof. John Milne.
1895. The Rev. John F. Blake.
1896. Dr. A. Smith Woodward.
1897. Dr. George Jennings Hinde.
1898. Prof. Wilhelm Waagen.
1899. Lt.-Gen. C. A. McMahon.
1900. Prof. John Edward Marr.
1901. Dr. Ramsay H. Traquair.
1902. { Prof. Anton Fritsch. / Mr. Richard Lydekker. }
1903. Mr. Frederick W. Rudler.
1904. Prof. Alfred G. Nathorst.
1905. Dr. Hans Reusch.
1906. Prof. Frank Dawson Adams.
1907. Dr. Joseph F. Whiteaves.
1908. Mr. Richard Dixon Oldham.
1909. Prof. Percy Fry Kendall.
1910. Dr. Arthur Vaughan.
1911. { Dr. Francis Arthur Bather. / Dr. Arthur Walton Rowe. }
1912. Mr. Philip Lake.
1913. Mr. Sydney S. Buckman.
1914. Mr. C. S. Middlemiss.
1915. Prof. Edmund J. Garwood.
1916. Dr. Charles W. Andrews.
1917. Dr. Wheelton Hind.

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE 'LYELL GEOLOGICAL FUND.'

1876. Prof. John Morris.
1877. Mr. William Pengelly.
1878. Prof. Wilhelm Waagen.
1879. Prof. Henry A. Nicholson.
1879. Dr. Henry Woodward.
1880. Prof. F. A. von Quenstedt.
1881. Prof. Anton Fritsch.
1881. Mr. G. R. Vine.
1882. The Rev. Norman Glass.
1882. Prof. Charles Lapworth.
1883. Mr. P. H. Carpenter.
1883. M. Edmond Rigaux.
1884. Prof. Charles Lapworth.
1885. Mr. Alfred J. Jukes-Browne.
1886. Mr. David Mackintosh.
1887. The Rev. Osmond Fisher.
1888. Dr. Arthur H. Foord.
1888. Mr. Thomas Roberts.
1889. Prof. Louis Dollo.
1890. Mr. C. Davies Sherborn.
1891. Dr. C. I. Forsyth-Major.
1891. Mr. George W. Lamplugh.
1892. Prof. John Walter Gregory.
1892. Mr. Edwin A. Walford.
1893. Miss Catherine A. Raisin.
1893. Mr. Alfred N. Leeds.
1894. Mr. William Hill.
1895. Prof. Percy Fry Kendall.
1895. Mr. Benjamin Harrison.
1896. Dr. William F. Hume.
1896. Dr. Charles W. Andrews.
1897. Mr. W. J. Lewis Abbott.
1897. Mr. Joseph Lomas.
1898. Mr. William H. Shrubsole.
1898. Mr. Henry Woods.
1899. Mr. Frederick Chapman.
1899. Mr. John Ward.
1900. Miss Gertrude L. Elles.
1901. Dr. John William Evans.
1901. Mr. Alexander McHenry.
1902. Dr. Wheelton Hind.
1903. Mr. Sydney S. Buckman.
1903. Mr. George Edward Dibley.
1904. Dr. Charles Alfred Matley.
1904. Prof. Sidney Hugh Reynolds.
1905. Dr. E. A. Newell Arber.
1905. Dr. Walcot Gibson.
1906. Prof. W. G. Fearnsides.
1906. Mr. Richard H. Solly.
1907. Mr. T. Crosbee Cantrill.
1907. Mr. Thomas Sheppard.
1908. Prof. T. Franklin Sibly.
1908. Mr. H. J. Osborne White.
1909. Mr. H. Brantwood Maufe.
1909. Mr. Robert G. Carruthers.
1910. Dr. F. R. Cowper Reed.
1910. Dr. Robert Broom.
1911. Prof. Charles Gilbert Cullis.
1912. Dr. Arthur R. Dwerryhouse.
1912. Mr. Robert Heron Rastall.
1913. Mr. Llewellyn Treacher.
1914. The Rev. Walter Howchin.
1914. Mr. John Postlethwaite.
1915. Mr. John Parkinson.
1915. Dr. Lewis Moysey.
1916. Mr. Martin A. C. Hinton.
1916. Mr. Alfred S. Kennard.
1917. Dr. A. Hubert Cox.
1917. Mr. Tressilian C. Nicholas.

AWARDS OF THE BIGSBY MEDAL,

FOUNDED BY THE LATE

DR. J. J. BIGSBY, F.R.S., F.G.S.

To be awarded biennially 'as an acknowledgment of eminent services in any department of Geology, irrespective of the receiver's country; but he must not be older than 45 years at his last birthday, thus probably not too old for further work, and not too young to have done much.'

1877. Prof. Othniel Charles Marsh.
1879. Prof. Edward Drinker Cope.
1881. Prof. Charles Barrois.
1883. Dr. Henry Hicks.
1885. Prof. Alphonse Renard.
1887. Prof. Charles Lapworth.
1889. Sir Jethro J. H. Teall.
1891. Dr. George Mercer Dawson.
1893. Prof. William J. Sollas.
1895. Dr. Charles D. Walcott.
1897. Mr. Clement Reid.
1899. Prof. T. W. Edgeworth David.
1901. Mr. George W. Lamplugh.
1903. Dr. Henry M. Ami.
1905. Prof. John Walter Gregory.
1907. Dr. Arthur W. Rogers.
1909. Dr. John Smith Flett.
1911. Prof. Othenio Abel.
1913. Sir Thomas H. Holland.
1915. Dr. Henry Hubert Hayden.
1917. Mr. Robert G. Carruthers.

AWARDS OF THE PRESTWICH MEDAL,

ESTABLISHED UNDER THE WILL OF THE LATE

SIR JOSEPH PRESTWICH, F.R.S., F.G.S.

'To apply the accumulated annual proceeds . . . at the end of every three years, in providing a Gold Medal of the value of Twenty Pounds, which, with the remainder of the proceeds, is to be awarded . . . to the person or persons, either male or female, and either resident in England or abroad, who shall have done well for the advancement of the science of Geology; or, from time to time to accumulate the annual proceeds for a period not exceeding six years, and apply the said accumulated annual proceeds to some object of special research bearing on Stratigraphical or Physical Geology, to be carried out by one single individual or by a Committee; or, failing these objects, to accumulate the annual proceeds for either three or six years, and devote such proceeds to such special purposes as may be decided.'

1903. John Lubbock, Baron Avebury.
1906. Mr. William Whitaker.
1909. Lady (John) Evans.
1912. Library extension.
1915. Prof. Émile Cartailhac.

AWARDS OF THE PROCEEDS OF THE BARLOW-JAMESON FUND,

ESTABLISHED UNDER THE WILL OF THE LATE

DR. H. C. BARLOW, F.G.S.

'The perpetual interest to be applied every two or three years, as may be approved by the Council, to or for the advancement of Geological Science.'

1879. Purchase of microscope.
1881. Purchase of microscope-lamps.
1882. Baron C. von Ettingshausen.
1884. Dr. James Croll.
1884. Prof. Leo Lesquereux.
1886. Dr. H. J. Johnston-Lavis.
1888. Museum.
1890. Mr. W. Jerome Harrison.
1892. Prof. Charles Mayer-Eymar.
1893. Scientific instruments for Capt. E. F. Younghusband.
1894. Dr. Charles Davison.
1896. Mr. Joseph Wright.
1896. Mr. John Storrie.
1898. Mr. Edward Greenly.
1900. Mr. George C. Crick.
1900. Dr. Theodore T. Groom.
1902. Mr. William M. Hutchings.
1904. Mr. H. J. Ll. Beadnell.
1906. Mr. Henry C. Beasley.
1908. Contribution to the Fund for the Preservation of the 'Grey Wether' sarsens on Marlborough Downs.
1911. Mr. John Frederick Norman Green.
1913. {Mr. Bernard Smith. / Mr. John Brooke Scrivenor.}
1915. Mr. Joseph G. Hamling.
1917. Mr. Henry Dewey.

AWARDS OF THE PROCEEDS OF THE 'DANIEL PIDGEON FUND,'

FOUNDED BY MRS. PIDGEON, IN ACCORDANCE WITH THE WILL OF THE LATE

DANIEL PIDGEON, F.G.S.

'An annual grant derivable from the interest on the Fund, to be used at the discretion of the Council, in whatever way may in their opinion best promote Geological Original Research, their Grantees being in all cases not more than twenty-eight years of age.'

1903. Prof. E. W. Skeats.
1904. Mr. Linsdall Richardson.
1905. Mr. Thomas Vipond Barker.
1906. Miss Helen Drew.
1907. Miss Ida L. Slater.
1908. Dr. James A. Douglas.
1909. Dr. Alexander M. Finlayson.
1910. Mr. Robert Boyle.
1911. Mr. Tressilian C. Nicholas.
1912. Mr. Otway H. Little.
1913. Mr. Roderick U. Sayce.
1914. Prof. Percy G. H. Boswell.
1915. Mr. E. Talbot Paris.
1916. Dr. John K. Charlesworth.
1917. Dr. Arthur Holmes.

Estimates for

INCOME EXPECTED.

	£ s. d.	£ s. d.
Compositions		35 0 0
Arrears of Admission-Fees	44 2 0	
Admission-Fees, 1917	126 18 0	
		171 0 0
Arrears of Annual Contributions	150 0 0	
Annual Contributions, 1917	1646 16 0	
Annual Contributions in advance	60 0 0	
		1856 16 0
Sale of the Quarterly Journal, including Longman's Account		88 8 0
Sale of other Publications		5 0 0
Miscellaneous Receipts		10 0 0
Interest on Deposit-Account and on War Loan*		35 0 0
Dividends on £2500 India 3 per cent. Stock	75 0 0	
Dividends on £300 London, Brighton, & South Coast Railway 5 per cent. Consolidated Preference Stock	15 0 0	
Dividends on £2250 London & North-Western Railway 4 per cent. Preference Stock	90 0 0	
Dividends on £2800 London & South-Western Railway 4 per cent. Preference Stock	112 0 0	
Dividends on £2072 Midland Railway 2½ per cent. Perpetual Preference Stock	51 16 0	
Dividends on £267 6*s*. 7*d*. Natal 3 per cent. Stock	8 0 0	
		351 16 0
		£2553 0 0

* The Council on January 24th, 1917, authorized the Treasurer to apply, on behalf of the Society, for £500 War Loan (1925–1947) Inscribed Stock.

the Year 1917.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
House-Expenditure:						
Taxes	0	15	0			
Fire- and other Insurance	31	6	0			
Electric Lighting and Maintenance	40	0	0			
Gas	15	0	0			
Fuel	50	0	0			
Furniture and Repairs	15	0	0			
House-Repairs and Maintenance	15	0	0			
Annual Cleaning	15	0	0			
Washing and Sundry Expenses	40	0	0			
Tea at Meetings	20	0	0			
				242	1	0
Salaries and Wages, etc.:						
Permanent Secretary	360	0	0			
" half Premium Life-Insurance	10	15	0			
Librarian	170	0	0			
Library Assistant	81	0	0			
Clerk	105	0	0			
Deputy Clerk	117	0	0			
Junior Assistant	55	12	0			
House-Porter and Wife	94	0	0			
Housemaid	57	2	0			
Charwoman and Occasional Assistance	20	0	0			
Accountants' Fee	10	10	0			
				1080	19	0
Office-Expenditure:						
Stationery	15	0	0			
Miscellaneous Printing	50	0	0			
Postages and Sundry Expenses	65	0	0			
				130	0	0
Library (Books and Binding)				120	0	0
Library Catalogue:						
Cards	10	0	0			
Compilation	50	0	0			
				60	0	0
Publications:						
Quarterly Journal, including Commission on Sale	700	0	0			
Postage on Journal, Addressing, etc.	80	0	0			
Abstracts of Proceedings, including Postage	100	0	0			
List of Fellows	40	0	0			
				920	0	0
				£2553	0	0

JAMES VINCENT ELSDEN, *Treasurer.*

February 5th, 1917.

RECEIPTS.

	£	s.	d.	£	s.	d.
To Balance in the hands of the Bankers at January 1st, 1916	127	13	7			
,, do. do. Deposit Account	500	0	0			
,, Balance in the hands of the Clerk at January 1st, 1916	7	19	9			
				635	13	4
,, Compositions				105	0	0
,, Admission-Fees:						
Arrears	44	2	0			
Current	170	2	0			
				214	4	0
,, Arrears of Annual Contributions	141	6	6			
,, Annual Contributions for 1916:—						
Resident Fellows	1689	19	6			
,, Annual Contributions in advance	64	7	0			
				1895	13	0
,, Publications:						
Sale of Quarterly Journal: *						
,, Vols. i to lxx (less Commission £4 0*s.* 9*d.*)	57	1	5			
,, Vol. lxxi (less Commission £2 14*s.* 1*d.*)	30	10	6			
				87	11	11
,, Other Publications (less Commission)				4	13	11
,, Miscellaneous Receipts				9	8	0
,, Interest on Deposit				38	17	7
,, Dividends (less Income-Tax):—						
£2500 India 3 per cent. Stock	59	1	4			
£300 London, Brighton, & South Coast Railway 5 per cent. Consolidated Preference Stock	12	6	0			
£2250 London & North-Western Railway 4 per cent. Preference Stock	73	13	9			
£2800 London & South-Western Railway 4 per cent. Preference Stock	91	14	0			
£2072 Midland Railway $2\frac{1}{2}$ per cent. Perpetual Preference Stock	42	0	9			
£267 6*s.* 7*d.* Natal 3 per cent. Stock	6	6	4			
				285	2	2
,, Income-Tax recovered				27	12	6
				£3303	16	5

* A further sum is due from Messrs. Longmans & Co. for Journal-Sales, etc.... £28 13 9

PAYMENTS.

	£	s.	d.	£	s.	d.
By House-Expenditure:						
Taxes		15	0			
Fire- and other Insurance	31	13	7			
Electric Lighting, Installation and Maintenance	33	19	10			
Gas	13	19	2			
Fuel	51	12	0			
Furniture and Repairs	107	5	1			
House-Repairs and Maintenance	86	3	3			
Annual Cleaning	11	2	6			
Washing and Sundry Expenses	42	17	6			
Tea at Meetings	18	4	7			
				397	12	6
„ Salaries and Wages:						
Permanent Secretary	360	0	0			
„ half Premium Life-Insurance	10	15	0			
Librarian	165	0	0			
Library Assistant	72	16	0			
Clerk	93	0	0			
Deputy Clerk	91	0	0			
Junior Assistant	54	12	0			
House-Porter and Wife	92	11	0			
Housemaid	53	8	0			
Charwoman and Occasional Assistance	17	13	6			
Accountants' Fee	10	10	0			
Extra Assistance	1	8	6			
Grant to Executors of the late Librarian	10	0	0			
War bonuses	38	17	0			
				1071	11	0
„ Office-Expenditure:						
Stationery	31	4	9			
Miscellaneous Printing	56	17	6			
Postages and Sundry Expenses	57	3	0			
				145	5	3
„ Library (Books and Binding, etc.)				136	11	2
„ Library-Catalogue:						
Cards	11	3	8			
Compilation	50	0	0			
				61	3	8
„ Publications:						
Quarterly Journal, Vol. lxxi, Paper, Printing, and Illustrations	581	19	7			
Postage on Journal, Addressing, etc.	69	9	0			
Abstracts of Proceedings, including Postage	96	17	10			
List of Fellows	50	6	6			
				798	12	11
„ Medals				14	5	6
„ Refund of Contribution Received in advance in 1915. (Fellow since deceased)				2	2	0
„ Balance in the hands of the Bankers at December 31st, 1916:						
Current Account	59	3	10			
Deposit Account	600	0	0			
„ Balance in the hands of the Clerk at December 31st, 1916	17	8	7			
				676	12	5
				£3303	16	5

We have compared this statement with the Books and Accounts presented to us, and find them to agree.

BERNARD SMITH, S. H. WARREN, } *Auditors.*

JAMES VINCENT ELSDEN, *Treasurer.*

February 5th, 1917.

Statements of Trust-Funds: December 31st, 1916.

'Wollaston Donation Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1916	30	7	7	By Cost of Medal	10	10	0
,, Dividends (less Income-Tax) on the Fund invested in £1073 Hampshire County 3 per cent. Stock	25	7	0	,, Award from the Balance of the Fund	19	17	7
,, Income Tax recovered	2	13	8	,, Balance at the Bankers' at December 31st, 1916	28	0	8
	£58	8	3		£58	8	3

'Murchison Geological Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1916	20	5	2	By Award to the Medallist	10	10	0
,, Dividends (less Income-Tax) on the Fund invested in £1334 London & North-Western Railway 3 per cent. Debenture Stock	32	15	4	,, Award from the Balance of the Fund	26	10	4
,, Income Tax recovered	3	1	8	,, Balance at the Bankers' at December 31st, 1916	19	1	10
	£56	2	2		£56	2	2

'Lyell Geological Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1916	50	13	0	By Award to the Medallist	25	0	0
,, Dividends (less Income-Tax) on the Fund invested in £2010 1*s.* 0*d.* Metropolitan $3\frac{1}{2}$ per cent. Stock	55	8	2	,, Award from the Balance of the Fund	40	3	3
,, Income Tax recovered	5	18	8	,, Balance at the Bankers' at December 31st, 1916	46	16	7
	£111	19	10		£111	19	10

'Barlow-Jameson Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1916	7	2	2	By Balance at the Bankers' at December 31st, 1916	19	13	9
,, Dividends (less Income-Tax) on the Fund invested in £468 Great Northern Railway 3 per cent. Debenture Stock	11	9	11				
,, Income Tax recovered	1	1	8				
	£19	13	9		£19	13	9

'Bigsby Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1916	3	2	5	By Balance at the Bankers' at December 31st, 1916	8	12	2
,, Dividends (less Income-Tax) on the Fund invested in £210 Cardiff 3 per cent. Stock	4	19	3				
,, Income Tax recovered	0	10	6				
	£8	12	2		£8	12	2

'Geological Relief Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1916	41	0	10	By Grants	10	10	0
,, Dividends (less Income-Tax) on the Fund invested in £139 3*s.* 7*d.* India 3 per cent. Stock	3	5	9	,, Balance at the Bankers' at December 31st, 1916	34	4	0
,, Income Tax recovered	0	7	5				
	£44	14	0		£44	14	0

'Prestwich Trust Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.	£	s.	d.
To Balance at the Bankers' at January 1st, 1916	56	11	7	By Balance at the Bankers' at December 31st, 1916:						
,, Dividends (less Income-Tax) on the Fund invested in £700 India 3 per cent. Stock	16	10	9	Current Account	16	14	11			
,, Income Tax recovered	1	15	4	On Deposit	60	0	0			
,, Interest on Deposit	1	17	3					76	14	11
	£76	14	11					£76	14	11

'Daniel Pidgeon Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1916	15	3	2	By Award	27	15	5
„ Dividends (less Income-Tax) on the Fund invested in £1019 1*s.* 2*d.* Bristol Corporation 3 per cent. Stock.	24	1	6	„ Balance at the Bankers' at December 31st, 1916	14	0	4
„ Income Tax recovered	2	11	1				
	£41	15	9		£41	15	9

SPECIAL FUNDS.

Hudleston Bequest.

Receipts.	£	s.	d.	Payments.	£	s.	d.	£	s.	d.
To Balance at the Bankers' at January 1st, 1916	33	0	8	By Balance at the Bankers' at December 31st, 1916:						
„ Dividends (less Income-Tax) on the Fund invested in £1000 Canada $3\frac{1}{2}$ per cent. Stock	27	11	3	Current Account	19	19	7			
„ Income Tax recovered	2	19	9	On Deposit	45	0	0			
„ Interest on Deposit	1	7	11					64	19	7
	£64	19	7					£64	19	7

Sorby Bequest.

Receipts.	£	s.	d.	Payments.	£	s.	d.	£	s.	d.
To Balance at the Bankers' at January 1st, 1916	33	0	7	By Balance at the Bankers' at December 31st, 1916:						
„ Dividends (less Income-Tax) on the Fund invested in £1000 Canada $3\frac{1}{2}$ per cent. Stock	27	11	3	Current Account	19	19	7			
„ Income Tax recovered	2	19	10	On Deposit	45	0	0			
„ Interest on Deposit	1	7	11					64	19	7
	£64	19	7					£64	19	7

We have compared this Statement with the Books and Accounts presented to us, and find them to agree.

JAMES VINCENT ELSDEN, *Treasurer.*
February 5th, 1917.

BERNARD SMITH,
S. HAZZLEDINE WARREN, } *Auditors.*

Statement relating to the Society's Property: December 31st, 1916.

	£ s. d.	£ s. d.
Balance in the Bankers' hands, December 31st, 1916:		
On Current Account	59 3 10	
„ Deposit „	600 0 0	
Balance in the Clerk's hands, December 31st, 1916	17 8 7	
		676 12 5
Due from Messrs. Longmans & Co., on account of the Quarterly Journal, Vol. LXXI, etc.	28 13 9	
Arrears of Admission-Fees	44 2 0	
Arrears of Annual Contributions (Estimated to produce £150 0*s.* 0*d.*)	403 6 0	
		476 1 9
		£1152 14 2
Funded Property, at cost price:—		
£2500 India 3 per cent. Stock	2623 19 0	
£300 London, Brighton, & South Coast Railway 5 per cent. Consolidated Preference Stock	502 15 3	
£2250 London & North-Western Railway 4 per cent. Preference Stock	2898 10 6	
£2800 London & South-Western Railway 4 per cent. Preference Stock	3607 7 6	
£2072 Midland Railway $2\frac{1}{2}$ per cent. Perpetual Preference Stock	1850 19 6	
£267 6*s.* 7*d.* Natal 3 per cent. Stock	250 0 0	
£2000 Canada $3\frac{1}{2}$ per cent. Stock	1982 11 0	
		£13716 2 9

[NOTE.—*The above amount does not include the value of the Library, Furniture, and stock of unsold Publications. The value of the Funded Property of the Society, at the prices ruling at the close of business on December 31st, 1916, amounted to* £7984 7*s.* 3*d.*]

JAMES VINCENT ELSDEN, *Treasurer.*

February 5th, 1917.

Award of the Wollaston Medal.

In handing the Wollaston Medal, awarded to Prof. Antoine François Alfred Lacroix, F.M.G.S., to Sir Archibald Geikie, O.M., for transmission to the recipient, the President addressed him as follows:—

Sir Archibald Geikie,—

For a Medal instituted 'to promote researches concerning the mineral structure of the Earth,' it would be difficult to find a fitter recipient than Prof. Lacroix, to whose labours in the domain of Mineralogy and Petrology our science is so deeply indebted. His researches on the optical and crystallographic constants of numerous minerals have given us a mass of useful data; but it has always been his practice to extend his investigations to the field as well as to the laboratory. His studies of the mode of occurrence, the mutual associations, and the manner of origin of a host of species have done much to rehabilitate Mineralogy as, not merely a department of Physics and Chemistry, but a fascinating branch of Natural History. His many separate papers deal with material from all parts of the world; but of chief importance will always be reckoned his four volumes on the Mineralogy of France and her Colonies, a single-handed work unique in its wide scope and comprehensive treatment.

In Petrology, too, Prof. Lacroix's contributions have been numerous and many-sided. Of special note for their influence upon the science are his researches on contact-metamorphism, contained in the Bulletins of the Geological Survey of France, his various memoirs treating of the inclusions in igneous rocks, and his comparative study of the volcanic products of Mont Pelé, followed by a like examination of the rocks of Vesuvius.

From the products of volcanoes to the physics of volcanic action is a natural transition, and in respect of both Prof. Lacroix's mission to Martinique in 1902 was eminently fruitful in results. In particular, he was able to elucidate two remarkable phenomena previously unrecognized or unappreciated: the peculiar plugs or domes formed under certain conditions by extruded lavas, and that most terrible of all volcanic effects—the *nuée ardente*.

As a diligent student of his writings, I feel a special pleasure in placing the Wollaston Medal in your hands for transmission

to Prof. Lacroix. With no less pleasure, I am sure, will all British geologists see his name added to a list which is already graced by the names of Élie de Beaumont and Ami Boué, Daubrée and Descloizeaux; and they will acclaim this award the more cordially since, in doing homage to a distinguished *savant*, we are honouring a citizen of a great nation, with which our own is linked, as we hope, by enduring ties.

Sir ARCHIBALD GEIKIE replied in the following words:—

Mr. PRESIDENT,—

It is both a signal honour and a welcome pleasure to me to have been requested by my friend Prof. Lacroix to receive this Medal on his behalf. He has asked me to express to you and to the Society his grateful thanks that you should have thought him worthy of your highest prize, and at the same time to assure you how deep is his regret that his official engagements prevent him from leaving Paris and being with us here to-day. You are aware that he has now added to his ordinary professional duties those of Secrétaire Perpétuel de l'Académie des Sciences, thus following, at no great interval of time, another eminent geologist of France, our lamented Foreign Member A. de Lapparent.

You have sketched with well-merited appreciation the wide range of investigation through which our latest Wollaston Medallist has pursued his studies. He has united with pre-eminent skill the detailed work of the laboratory with an appeal to the essential evidence which can only be obtained in the field. In this latter branch of research he has been fortunate in having as his companion and fellow-labourer a devoted and enthusiastic wife. Madame Lacroix, as the daughter of Ferdinand Fouqué, has inherited her father's scientific ardour, and has proved herself to be as capable and enduring a mountaineer as her husband.

Prof. Lacroix has sent me a brief address to you, Mr. President, expressive of his grateful recognition of the honour which the Geological Society has conferred upon him. His handwriting, however, is so difficult to decipher that I have ventured to make a translation of this Address, which I will now read:—

'Mr. PRESIDENT,—

'No honour could be more appreciated by me than that which the Geological Society of London has conferred upon me. Over and above the pride which I feel in this award from so many competent judges, among whom are not a few who pursue the same researches as those to which I have devoted

myself, there is added, in present circumstances, the further gratification to see the ties strengthened which from old times have linked the men of science in our two countries—Britain now striving with all her power and all her soul, hand in hand with France in defence of Right and Liberty.

'You have wished this year, I am sure, to honour in a more special manner French Geology, and this adds a further reason why I should be touched that you have chosen me as the recipient of your prize.

'In being so good as to represent me at your Anniversary, Sir Archibald Geikie, for whose work I have as great an admiration as I have respectful esteem for him personally, will convey to you, so far as that is possible, my regret that my official duties here prevent me from being present with you, and expressing with my own living voice all my gratitude.

'Among the distant memories of my student-days there rises in my mind the recollection of my old and dear master Descloizeaux, the friend of your Miller, carefully taking out of a drawer in his writing-table the Wollaston Medal, which he had some time before received from you, and showing it to his pupils as one of the most valuable tokens of esteem that he had ever received in the course of his long and laborious career.

'How indeed could one not be proud, though with all humility, to see one's name inscribed in your golden book below those of the Founders of our Science, and following those among you who with such brilliance continue to maintain their great and glorious inheritance?

'Be so good, Mr. President, as to receive the expression of my highest consideration.

A. LACROIX.'

AWARD OF THE MURCHISON MEDAL.

The PRESIDENT then handed the Murchison Medal, awarded to Dr. GEORGE FREDERIC MATTHEW, to Dr. J. E. MARR for transmission to the recipient, addressing him as follows:—

Dr. MARR,—

In awarding the Murchison Medal to Dr. G. F. Matthew, the Council desires to mark its high appreciation of the services which he has rendered to Geology, more particularly by his researches among the Lower Palæozoic rocks of New Brunswick.

Engaged for many years in official duties, and enjoying little of the advantages which come from association with fellow-workers and from access to large libraries and museums, he has still found time and means to make valuable contributions to our science. So long ago as 1865 he communicated an important paper to this Society, but most of his results have seen the light in Canadian and American journals. Of first importance must be reckoned his 'Illustrations of the Fauna of the St. John Group,' published by the Royal Society of Canada, a work embodying much patient and skilful research. A paper which appeared in 1895, in the Transactions of the New York Academy of Sciences, contained the first

account of the *Protolenus* fauna. Of other important contributions which Dr. Matthew has made to Lower Palæozoic geology, I may mention his discoveries of the Etchiminian and the still older Coldbrook fauna beneath what had previously been considered the oldest fossiliferous horizon in New Brunswick. His work has been distinguished throughout by a happy combination of stratigraphical skill with palæontological knowledge, and some of his studies, such as those on the evolution of the Cambrian Trilobites, have had far-reaching consequences.

I have much pleasure in handing this Medal to you for transmission to the veteran Canadian geologist, and hope that he will see in it a token that his labours in the field of science are not without recognition in this country.

Dr. Marr replied in the following words:—

Mr. President,—

The interval that has elapsed since the award of the Murchison Medal has been too short, in these times of stress, to allow Dr. Matthew to send an acknowledgment. Had he done so, he would doubtless have expressed to the Council his gratification at the honour conferred upon him.

I am glad to receive the Medal on his behalf, so that I, an old friend, may add my appreciation of the value of his work, although this is unnecessary after the sympathetic words which you, Sir, have offered concerning it.

Dr. Matthew's name is the latest in a long list of Canadians on our roll of honour, for the men of the Dominion have excelled in the field of our science, as latterly in another and a sterner field.

I feel that I may, on behalf of the Fellows of the Society, express the wish that our Medallist, veteran though he be, may yet enjoy many years in the study of his favourite science.

Award of the Lyell Medal.

In handing the Lyell Medal, awarded to Dr. Wheelton Hind, F.R.C.S., to Dr. A. Smith Woodward for transmission to the recipient, the President addressed him as follows:—

Dr. Smith Woodward,—

The Lyell Medal has been awarded by the Council to Dr. Wheelton

Hind as a token that he has, in the words of its Founder, 'deserved well of the Science.'

On the side of descriptive and systematic palæontology his two memoirs on the Carboniferous Lamellibranchiata, published by the Palæontographical Society, have long taken rank as standard works, and he has supplemented them from time to time by many other contributions dealing with the same subject. Further, he has brought his palæontological knowledge to bear upon important questions of stratigraphy, and has shown that the lamellibranch faunas of different groups of rocks furnish valuable data for purposes of comparison. In this way he has taken no small part in the correlation of the Carboniferous strata in different areas in Britain, and has further pushed his enquiries to the Continent of Europe.

The quantity, as well as the quality, of his geological work seems the more remarkable, when we remember that his researches have been carried out in the intervals, none too frequent, of a busy professional life. In conferring upon him this mark of recognition, so well earned, we are thus honouring one of those amateur workers to whom British Geology has always been signally indebted. In presenting it I express the hope that, when happier days bring again some allowance of leisure, Dr. Hind will be able to renew those investigations which have already proved so rich in results.

Dr. Smith Woodward replied in the following words:—

Mr. President,—

I shall have much pleasure in transmitting the Lyell Medal to my friend Dr. Wheelton Hind, on whom it has been so worthily bestowed. Geological science has always been greatly indebted to the medical profession for important advances made in their brief intervals of leisure, and Dr. Hind has for many years excellently maintained the old tradition. Recognizing the importance of combining work in the field with detailed palæontological research in the study, he soon became one of the most successful exponents of the modern methods of stratigraphical geology. Beginning researches on the Carboniferous rocks in his own district of North Staffordshire, he has gradually extended his domain until, as you have well said, Sir, he has taken no small part in the correlation of the Carboniferous strata of Britain. So soon as he is released from the military duties which prevent his

attendance at the meeting to-day, I feel sure that Dr. Hind will return with renewed vigour to the geological work which has so long been his recreation; and he desires me to express his best thanks to the Council of the Geological Society for the stimulating Award with which they have honoured him.

Award of the Bigsby Medal.

The President then handed the Bigsby Medal, awarded to Mr. Robert George Carruthers, to Dr. A. Strahan, Director of H.M. Geological Survey, for transmission to the recipient, addressing him as follows:—

Dr. Strahan,—

The Bigsby Medal has been awarded to Mr. Carruthers by the Council as an acknowledgment of his eminent services to Scottish Geology. As an officer of the Geological Survey he has investigated considerable areas of the ancient rocks of the Highlands, the Carboniferous of the Scottish Midlands, and the Old Red Sandstone of Caithness; and in each of these fields his labours have yielded results which possess more than a local interest. On the side of pure Palæontology he has made important additions to our knowledge of the Corals, in particular by his memoir dealing with the morphology of the Rugosa; but especially are geologists indebted to him for the use which he has made of the Corals in the zonal subdivision of the Carboniferous succession. Of other palæontological contributions having a direct stratigraphical application, I will recall only his discovery of a Pendleside fauna in the Calciferous Sandstone Series of Lanarkshire and his reference of the fish-fauna of Achanarras to its true position in the Old Red Sandstone sequence. Among his services to Economic Geology, his revision of the memoir on the Oil-Shale Fields of the Lothians is especially worthy of mention.

The Founder of this Medal, in fixing an age-limit for the recipient, made clear his intention that regard should be had, not only to performance in the past, but to promise for the future. Confident that in this case the one is a sure guarantee of the other, we ask him to receive this Award in the double acceptation of a tribute and an encouragement.

Dr. Strahan replied in the following words:—

Mr. President,—

It is a great pleasure to me to receive, on behalf of my colleague on the Geological Survey, this testimony of the value that the Council attaches to his work. You have referred in generous terms to Mr. Carruthers's contributions to our knowledge of Scottish Geology, and to his researches in pure Palæontology. His application of scientific methods of investigation to the Corals has done much to elucidate stages of evolution in those lowly organisms, and I believe that your recognition of this branch of his work will be especially gratifying to him. In Economic Geology the demands made upon the staff by the exigencies of war were sudden and imperative, and no one knows better than myself how well Mr. Carruthers and his colleagues responded to the call, and for the time resisted the fascinations of abstract science.

Mr. Carruthers, writing amid the distractions of the Western Front, tells me that it is

'almost impossible to give any adequate expression of my gratitude to the Society for their award of the Medal . . . . . As the bulk of my work has been concerned with Economic Geology, the honour of this award is shared equally with my comrades on the Survey . . . . In the field of abstract science my ventures have been little more than tentative. I hope that the generous encouragement that they have always received from the Society may ultimately be repaid in some degree. The obligation is, of course, greatly increased by this additional proof of trust.'

May I express the hope, for myself and for the Fellows of the Society, that it will not be long before Mr. Carruthers can resume his scientific work and justify the confidence that you have so gracefully expressed in his promise for the future?

Award from the Wollaston Donation Fund.

In presenting the Balance of the Proceeds of the Wollaston Donation Fund to Percy George Hamnall Boswell, D.Sc., the President addressed him as follows:—

Dr. Boswell,—

The Balance of the Proceeds of the Wollaston Donation Fund has been awarded to you by the Council in recognition of your work in East Anglia, by which you have added to our knowledge

of the subterranean as well as the superficial geology of that area. In your earlier contributions you examined the origin of the existing river-system of Suffolk, and also endeavoured to define the limits of extension of the Lower Glacial deposits of Norfolk into the more southerly county. You have also made instructive researches into the lithology and mineralogy of many of the sedimentary deposits of East Anglia. In a paper read before this Society two years ago you employed this method, in conjunction with stratigraphical observation, in a comprehensive study of the Lower Eocene strata of the area, and drew interesting conclusions concerning the geography of the period and even the tectonics of the country. Your more recent investigations concerning sands suitable for glass-making have a direct practical application, of much importance at the present time.

Some part of your work has been the outcome of a grant from the Daniel Pidgeon Fund, and the good use which you made of that opportunity assures us that you will regard the present Award as an incentive to new enterprises in the service of Geology.

Award from the Murchison Geological Fund.

The President then handed the Balance of the Proceeds of the Murchison Geological Fund, awarded to Dr. William Mackie, to Dr. W. T. Gordon, for transmission to the recipient, addressing him as follows:—

Dr. Gordon,—

The Balance of the Proceeds of the Murchison Geological Fund has been awarded by the Council to Dr. Mackie in recognition of his contributions to the geology of Northern Scotland. A skilled chemist as well as a keen petrologist, he has utilized in this way his leisure as a medical practitioner during the last twenty years.

By his investigation of the sandstones of Eastern Moray he has thrown light, both on the source of the material and on the climatic conditions which prevailed during its deposition. In the cement of these sandstones he detected traces of the heavy metals, and his enquiry led to the discovery in quantity of barytes and fluor in the

Elgin Trias. His petrographical work includes an interesting study of the granites of the North of Scotland, and he has also carried out a large series of chemical analyses of igneous and sedimentary rocks in order to elucidate theoretical questions suggested in the course of his researches.

His recent discovery of plant-bearing cherts in the Old Red Sandstone of Rhynie (Aberdeenshire), has added a new interest to that formation. Dr. Kidston and Prof. Lang recognize these cherts as silicified layers of peat, and a new class of vascular cryptogams, the *Psilophytales*, has been made for the reception of the plants which they contain.

I ask you, in forwarding this Award to Dr. Mackie, to convey to him our hope that he will thereby be encouraged to continue the researches which he has hitherto pursued with such enthusiasm.

Awards from the Lyell Geological Fund.

The President then presented a moiety of the Balance of the Proceeds of the Lyell Geological Fund to Arthur Hubert Cox, Ph.D., and addressed him in the following words :—

Dr. Cox,—

The Council has awarded to you one moiety of the Proceeds of the Lyell Fund in recognition of the value of your work among the Lower Palæozoic rocks. Since you read before this Society, five years ago, a paper on the Pedwardine Inlier, you have devoted much time to geological researches in Wales, both South and North. Your paper on the Abereiddy and Abercastle district was a valuable contribution to the stratigraphy and tectonics of Pembrokeshire, and gave evidence of skilful and accurate work in the field. On the petrological side, too, it added to our knowledge of the Ordovician igneous rocks, a subject to which you have also given attention elsewhere. Your work in the Cader Idris district, of which we have as yet only a preliminary account, seems to be of the same thorough quality; and, in thus marking our appreciation of what you have already done, we look forward to results not less important from your geological labours in the time to come.

In handing the other moiety of the Balance of the Proceeds of the Lyell Geological Fund, awarded to TRESSILIAN CHARLES NICHOLAS, M.A., to Mr. H. WOODS, for transmission to the recipient, the PRESIDENT addressed him as follows:—

Mr. WOODS,—

A moiety of the Proceeds of the Lyell Fund has been awarded to Mr. T. C. Nicholas as a mark of appreciation of his work on the older Palæozoic rocks of Carnarvonshire. The results of that work are represented first by a paper on the Geology of the St. Tudwal's Peninsula, in Lleyn, read before this Society in 1914. Therein he gave a comprehensive account of the succession, fossil contents, and classification of the Cambrian strata of the district, and established the unconformity which exists between these beds and the overlying Ordovician. This paper was supplemented in the same year by a palæontological one dealing with the rich trilobitic fauna, of Middle Cambrian age, which his researches had discovered. A number of new and interesting species were described, and the succession of forms was correlated with that recorded for other areas.

As an old friend of Mr. Nicholas, and one who has seen something of the difficulties presented by the Lleyn district, I am pleased that it falls to my lot to extend to him, on behalf of the Council, this token of recognition of his geological and palæontological work.

AWARD FROM THE BARLOW-JAMESON FUND.

The PRESIDENT then presented the Balance of the Proceeds of the Barlow-Jameson Fund to Mr. HENRY DEWEY, addressing him as follows:—

Mr. DEWEY,—

The Proceeds of the Barlow-Jameson Fund have been awarded to you in recognition of your services to Geology and as an encouragement to you for the future. In the record of your geological work the first place belongs to your researches in North Cornwall, where you were engaged as an officer of the Geological Survey. There your mapping led you to recognize a number of

subdivisions of the Devonian strata and to determine their natural sequence, and with this help you were able to demonstrate the existence of important overthrusts in that area. The peculiar features of the 'pillow-lavas' intercalated in the Upper Devonian also engaged your attention, and your paper on the 'spilitic series,' written in collaboration with Dr. Flett, has proved a valuable contribution to Petrology. Of not less consequence, of another kind, were your paper on the Raised Beach of North Devon and that which you read before this Society a year ago on the Origin of River-Gorges in Cornwall and Devon. Your removal from the West of England to the Thames Valley introduced you to new problems, to which you have brought the same zeal and insight, and it is our hope that you will find in the present Award an incentive to further investigations in the field of Geology.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

Alfred Harker, M.A., LL.D., F.R.S.

The death-roll for the last twelve months is a heavy one, and includes not a few well-known names. In preparing notices of some of our deceased Fellows, I have used various sources of information, but especially I must acknowledge the help kindly given by Prof. Cayeux, Mr. Lamplugh, Prof. Skeats, and Mr. Barrington Brown, Jr.

The death of Jules Gosselet, in his 84th year, removes the doyen of French geologists, and one whose name stood second on the roll of our Foreign Members. Born at Cambrai on August 19th, 1832, he very early gave evidence of scientific aptitudes of a high order. After holding several minor appointments, he was chosen in 1864 Professor of Geology & Mineralogy in the Faculty of Sciences at Lille, a place which became thenceforth his home and the centre of his multitudinous activities. His immediate task was no light one. The Chair was newly created; library and museum were alike wanting; and science did not at that time enlist much interest in a busy industrial city. This last difficulty disappeared like the rest before the zeal of the young Professor; and indeed his subsequent labours must have convinced the most sceptical of the immense material benefit which may accrue to a country from the cultivation of pure science.

Gosselet's whole-hearted devotion to his work, and his ability to communicate his enthusiasm to others, made him an ideal teacher. His old students speak of him with an affectionate admiration, which is a high tribute to his personal qualities no less than to his powers as an instructor. The time and energy not absorbed by professional duties he devoted to geological investigation. Here, too, his example proved inspiring, for he was chiefly instrumental in founding in 1870 the Société Géologique du Nord, of which he continued to be to the last the guiding spirit.

Even before settling at Lille Gosselet had been attracted to the Ardenne, already made famous by the pioneer labours of Omalius d'Halloy and Dumont, and it was to the geology of that country that he now addressed himself. He brought to the task a laborious

patience, joined to an insight which had something of the detective's acumen and something of the poet's imagination. During ten years he produced in rapid succession papers treating of the general structure of the district, the stratigraphy and fauna of the Devonian formations, the ridges of Cambrian rocks which rise in the midst of the younger strata, and the remarkable metamorphic effects induced in connexion with the folding and overthrusting. His results were finally collected in the masterly monograph entitled 'L'Ardenne,' which appeared in 1888, and was at once recognized as a work of the first rank.

It would take long to enumerate all the contributions which Gosselet made in succeeding years to almost every department of geology. Remarkable for originality and freshness of interest, they often had also important practical applications. Of chief moment was the investigation of the structure of the Franco-Belgian coal-basin. This was indeed the natural complement of Gosselet's study of the Ardenne, and he was able to show how the Ardenne massif, or its prolongation, has been driven over the southern margin of the coal-basin. This work had a decided influence upon the doctrines then current concerning the structure of the Alps, while on the practical side it led to an extension of the workable coalfields. Gosselet was also attached to the Geological Survey of France, and was responsible for numerous sheets of the map with accompanying memoirs.

The value of his scientific labours was recognized both at home and abroad. The Academy of Sciences of Paris had awarded him the Bordin Prize in 1881, and when many years later the membership of the Academy was extended to provincial savants, Gosselet's name figured on the first list. Our Society awarded him the Murchison Medal in 1882, and three years later elected him a Foreign Member.

Still hale in mind and body at 70, the Professor was forced by an unwelcome age-limit to relinquish his Chair; but a kindly fate sent him for successor his old pupil and attached friend Dr. Charles Barrois. An unofficial place was found for the elder man, and in the leisure of retirement he saw merely enlarged opportunity for geological activities. When darker days came, and Lille fell into the hands of an ungenerous enemy, the veteran geologist refused to quit the scene of his long labours. His last illness was contracted while striving to repair the havoc wrought by an explosion among his cherished collections. He died on March 20th, 1916,

and rests in the little cemetery of Landrecies, the home of his boyhood.[1]

John Wesley Judd was born at Portsmouth on February 18th, 1840. His father was of a Kentish family long settled in the Isle of Wight, and his mother was of Scottish descent. His devotion to natural science declared itself at an early age; but, although he had obtained first-class certificates in Geology and Mineralogy from the Department of Science & Art, he found at first no opening in this direction. He accordingly became in 1859 a master in a school at Horncastle, in Lincolnshire. There he remained for three years, pursuing at the same time his studies in chemistry and devoting his holidays to geological excursions in the neighbourhood. In 1863, making another attempt to realize his aspirations towards a scientific career, he entered the Royal School of Mines, and was rewarded by winning one of the newly instituted Royal Exhibitions. His design was to devote himself for a time to research work, but in this he was again disappointed, and we next find him engaged as an analytical chemist in iron and steel-works at Sheffield. It was there that he made the acquaintance of Sorby, and was introduced by him to the new method of studying rocks in thin slices.

Judd's residence at Sheffield terminated abruptly by reason of a railway-accident, from the consequences of which he suffered for a long time. Forbidden to undertake any regular employment, he turned again to his geological work in Lincolnshire. By a stratigraphical and palæontological study of the strata at the base of the Chalk Wolds he was able to correlate them with the Neocomian of the Continent; and, extending his investigation to the Yorkshire coast, he there identified the same zones under a different facies. These researches formed the subject of his first two communications to our Society. He next carried out a revision of the Lower Oolites of Lincolnshire, and extended it into Yorkshire in one direction and into the Midland counties in the other. This he developed further in the course of his work on the Geological Survey, which he joined, at the instance of Ramsay, in 1867, and the results were embodied in the memoir on the Geology of Rutland which appeared, after some delay, in 1875.

[1] For many of the facts here recorded I am indebted to an interesting and sympathetic notice by Prof. L. Cayeux, in the 'Revue générale des Sciences,' July 15th, 1916.

In the meantime Judd had quitted the Survey, and presently found himself in a position to resume independent work in the field. He chose as a promising subject of study the Secondary rocks of Scotland. Beginning with the isolated and little-known exposures of these strata on the North-East coast, he was able after two years of work to make out the true succession and correlation of the several formations, ranging from the Trias to the Upper Oolites. He next transferred his attention to the West Coast and the Inner Hebrides; but there he soon became absorbed in a new interest. The Mesozoic rocks of the west have been buried under great floods of lava of Tertiary age, and are only partially exposed as the result of profound erosion in conjunction with plateau-faulting. At certain centres, too, masses of Tertiary plutonic rocks have broken through, and now build the mountains of Skye, Rum, and Mull. Little systematic work had been done upon these late igneous rocks since the pioneer days of Macculloch, and Judd threw himself into the task with characteristic energy. It was no light undertaking, for the area is large, much of the ground is not easily accessible, and no good topographical maps were then in existence. As the result of his investigations, he was led to regard the volcanic rocks of the Inner Hebrides as the products of five great volcanoes, the much-eroded cores of which are now represented by the chief plutonic complexes of the region. He recognized further a certain succession in time among the volcanic rocks, acid lavas and agglomerates being succeeded by basic. If those who have followed him in the same field, working under more advantageous conditions, have not confirmed all his conclusions, they have still recognized their great indebtedness to him who led the way. His results will remain an important contribution to the ultimate solution of the problem, as well as a memorable example of a generalization boldly conceived and laboriously worked out.

The memoir which was the outcome of these researches, published in the Quarterly Journal of the Geological Society in 1874, attracted the notice of some of the leading geologists of the day, and in this way the author made the acquaintance of Sir Charles Lyell and Scrope, and later also of Darwin. The friendship and encouragement of these veterans was of great value to the younger man. It was under Scrope's auspices that he enlarged his knowledge of volcanic phenomena by visits to the active and extinct volcanoes of Italy, Hungary, and Bohemia, the results of which

were seen in a series of papers published in the 'Geological Magazine.' In the course of these studies he was led to consider more closely the nature of igneous action, and at this time also he first formed that conception of different 'petrographical provinces' which has since proved so fruitful.

The turning-point of Judd's career came in 1876, when he was chosen to succeed Ramsay as Professor of Geology in the Royal School of Mines. The School was then housed in Jermyn Street, but a little later the Geological division was removed to South Kensington, where it subsequently became part of the Royal College of Science. Advised by Huxley, and profiting also by what he had seen in Continental schools of geology, the new Professor built up a thorough and comprehensive system of instruction, in which the practical element occupied a prominent place. His own extensive knowledge and organizing talent, with the help of a succession of able assistants of his own training, soon placed the Royal College of Science in the foremost rank as a training-school for geologists. The cordial relations which he always cultivated with his students did not cease when they passed out of his class, and many geologists at home and abroad still hold the Professor in grateful remembrance.

His professorial engagements did not, however, preclude other interests. In 1865 he had been elected a Fellow of this Society, and in 1878 he had become one of its Secretaries, which office he held until his election to the Presidency eight years later. In the same year, too, he had married Jeannie Frances Jeyes, a niece of the Midland geologist Samuel Sharp. Opportunities for field-work were now more restricted; but, besides carrying out a revision of the Tertiaries of the Hampshire Basin, he found time to revisit the Western Isles and to make there a large collection of the igneous rocks. With this material he entered upon a new line of research, and in the years following he produced a series of petrographical memoirs remarkable for their originality and breadth of view. It was more particularly for this work that he received in 1891 the award of the Wollaston Medal; but many other subjects from time to time engaged his attention, and it is impossible in a short notice to do justice to the long list of his published works, showing an activity which embraced almost every branch of geology.

After his retirement in 1905, though his pen was not idle, his energy began to suffer from the state of his health. A partial

deafness cut him off from social intercourse, but infirmity did not impair the genial temper, the quiet helpfulness and consideration for others, which endeared him to his friends. During the last year of his life he suffered from a nervous malady, under which he gradually sank, and he died at his residence at Kew on March 3rd, 1916, a fortnight after his 76th birthday.[1]

Joseph Henry Collins died on April 12th, 1916, aged 75, after a long life devoted to the study of the geology, mineralogy, chemistry, and metallurgy of Cornwall and the Cornish ore-deposits. Among his numerous scientific writings may be mentioned his 'Handbook to the Mineralogy of Cornwall & Devon' (1871); 'The Hensbarrow Granite District' (1878); 'Cornish Tin-Stones & Tin-Capels,' issued in 1888 as a revised edition of papers previously communicated to the Mineralogical Society; and a memoir 'On the Origin & Development of Ore-Deposits of the West of England,' published in the Journal of the Royal Institution of Cornwall, 1890–95. He was a well-known figure in Cornwall, where he was associated with all the local scientific societies. He received the Henwood Medal of the Royal Institution of Cornwall in 1893, and the Bolitho Medal of the Royal Geological Society of Cornwall in 1898. He was elected a Fellow of this Society in 1869, and contributed to its Quarterly Journal a number of papers dealing with Cornish geology and with Canadian metalliferous deposits.

Charles Thomas Clough was born on December 23rd, 1852, at Huddersfield, where his father held the office of Town Clerk. From school at Rugby he passed to St. John's College, Cambridge, and, after graduating in 1874 in the first class of the Natural Sciences Tripos, joined the Geological Survey. He began work in Teesdale, and his first original production was a paper on the section at High Force, read before this Society in 1876. Later he was engaged in the Cheviot district, and in 1884 he was transferred, with other members of the staff, from the English to the Scottish branch. The detailed investigation of the North-West Highlands was then beginning, and in this work Clough was soon taking an important part. He was responsible for a portion of the critical

[1] I have borrowed largely from appreciative notices in the 'Geological Magazine' for 1905 and 1916.

area in West Sutherland and also for the Loch Maree district. In the spring, when the mountains were not yet clear of snow, and in the autumn, when the deer-forests were closed, he was engaged in the Cowal peninsula of Argyllshire. Later he surveyed much difficult ground in the Glenelg district, the south-eastern part of Skye, and Easter Ross.

In 1902 Clough was made a District Geologist, and soon afterwards took over the charge of the Survey work in Northern Argyllshire and the Isle of Mull, while he was occupied during the spring and autumn with the revision of the Scottish coal-fields. It was in the course of this latter work that he met his death, being run over in a railway-cutting, and sustaining injuries to which he succumbed three days later, on August 27th, 1916.

Clough was essentially a geological mapper, and, whether for skill in unravelling complicated structures, or for minute and accurate detail, his maps have probably never been equalled. Of the numerous official memoirs of which he was author or joint-author the most important are his parts of 'The Geology of Cowal,' published in 1897, and 'The Geological Structure of the North-West Highlands,' issued ten years later. His writings are characterized by scrupulous accuracy concerning the facts of observation, combined with a conscientious care in the drawing of conclusions. The reader soon acquires the conviction that any statement advanced by Clough may be accepted without hesitation.

While deeply absorbed in his geological work, he took also a keen interest in social questions. His personal tastes and habits were of the simplest. His gentle nature, his transparent sincerity, his modesty concerning his own work, and his generous appreciation of that of others, gave him a warm place in the hearts of all who knew him. In 1906 he received recognition from this Society in the form of the Murchison Medal; from 1908 to 1910 he was President of the Geological Society of Edinburgh; and only a month before his death the University of St. Andrews conferred upon him the degree of LL.D. He leaves a widow with one son and two daughters.

By the death of Clement Reid we have lost an assiduous worker who, during a Fellowship of forty years, has done much to forward the interests of the Society, both by his scientific contributions and by his services on the Council. The value and promise of his work were recognized by the award to him of the Murchison

Fund in 1886 and of the Bigsby Medal in 1897. He was elected into the Royal Society in 1899. He served on our Council in 1892–95, and again in 1912–16, being a Vice-President for the last three of these years. He also served on the Council of the Linnean Society.

Born on January 6th, 1853, Reid had the investigator-strain in his blood, being a great-nephew of Michael Faraday. He owed little to early training, for circumstances compelled him to enter business while still a youth; but the nascent spirit of research was stirred in him at the Juvenile Lectures of the Royal Institution, and he set out courageously to qualify himself for a scientific career. Overcoming all difficulties, he obtained in 1874 a post on the Geological Survey as Assistant-Geologist, and entered with enthusiasm upon what was to be his life's work. After a short spell in the South-West of England, his duties took him to the Eastern Counties and to the investigation of the complicated Pliocene and Pleistocene deposits of the Norfolk coast, a task in which he quickly proved his ability both as geologist and as naturalist. In the course of this work he devoted special attention to the discovery and identification of the seeds of plants contained in some of the deposits. This branch of research he afterwards continued to pursue with conspicuous success, and became recognized as a leading authority on the subject among Continental as well as British geologists.

Reid was next engaged on the north-eastern moorlands of Yorkshire, and afterwards in Holderness and East Lincolnshire. Later he was sent to map the South Downs and the coastal tract of Sussex, passing thence through Hampshire and part of the Isle of Wight into Dorset and Wiltshire. His descriptions of these areas are contained in a series of official memoirs published between the years 1882 and 1903, and they are characterized, as are all his writings, by clarity of expression and a grip of essentials. Meanwhile he had produced also a general monograph on the Pliocene deposits of Britain, during the preparation of which he paid visits, for purposes of comparison, to Belgium and Italy. His researches, however, never stopped at the bounds of his official duty: all his leisure was spent in furthering the studies which he had at heart, and he was ever ready to bestow time and pains in helping any other worker who stood in need of his special knowledge. His papers contributed to scientific societies and periodicals were many, and cover a wide range of subjects, but especially the plant-life

of the later geological periods, the climatic conditions indicated by various kinds of deposits, and questions relating to the early history of Man in this country. By their subject-matter and the able manner of its presentment some of these papers have taken a standard place in geological literature.

In 1897 Reid married Miss Eleanor M. Wynne Edwards, who took an active share in most of his later work. In 1899 he summed up his knowledge of the botanical conditions of the past in a book entitled 'The Origin of the British Flora,' which appealed equally to geologists and to botanists; and later, in 1913, he dealt in the same way with the subject of our 'Submerged Forests.' After his promotion in 1901 to the rank of District Geologist, he was in charge of the Survey work in the difficult area of Cornwall and Devon. This was completed in 1909, and the results are recorded in memoirs written in conjunction with his colleagues. It was in recognition of this work that Reid received the Bolitho Medal of the Royal Geological Society of Cornwall. In 1908 he made a visit to Cyprus, for the purpose of advising the Colonial Office on matters connected with the water-supply of the island. From 1909 until his retirement from official life early in 1913, he had charge of the survey of the area round London.

Freed from the trammels of office, Reid left London for the quiet of a new home at Milford-on-Sea, on the borders of the New Forest, where he concentrated his energies upon palæobotanical researches. Among other studies, he made, in collaboration with his wife, a thorough examination of the interesting plant-fossils from Holland, which were described in a series of joint papers upon the Pliocene flora of the Dutch-Prussian border. He also began with Mr. J. Groves a promising investigation of the fossil Characeæ, some of the first results of which were brought before this Society only a few weeks ago. But the check came when he was in full career, with every prospect of further achievement. He died after a short illness, and without much suffering, on December 10th, 1916.

Clement Reid's sincerity of mind and unswerving devotion to the pursuit of knowledge were apparent to all who knew him. His writings constantly evince a sense of the imperfection of our present attainment and the tentative character of the results achieved. Always he lays stress upon the need for more facts, and avoids the temptation to round off artificially the work already done. In his outlook he was essentially a naturalist, and he

deprecated any attempt to solve the problems of the earth's past from geological data alone. He persevered to the end in his self-appointed task, and his latest thoughts were still for his work. [G. W. L.]

The death of Bedford McNeill, at the age of 55, takes from us a prominent exponent of Applied Geology, and deprives the Society of a valued officer. Trained at the Royal School of Mines, Jermyn Street, he entered upon his profession of mining engineer in 1880, and was employed to inspect and report on mines in Mexico, Colorado, and other parts of the world. Settling later in London, he became consulting engineer to a number of important mining companies, and attained a leading place in the profession. In the year 1913–14 he was President of the Institution of Mining & Metallurgy, and his Address on that occasion showed that he held high views as regards the importance of geological science in relation to all mining undertakings. His intervals of leisure were employed during many years in compiling the Telegraphic Code which has made his name widely known, a work of much careful labour, which was first issued in 1893, and was revised and enlarged in 1908.

Bedford McNeill had become a Fellow of this Society in 1888. He served on the Council in 1904–1907, and at the time of his death had held for four years the important office of Treasurer. His loss is deplored by a large circle of friends, to whom his happy disposition and genial humour rendered him always welcome. He died at his residence at Claygate (Surrey), after a short illness, on September 18th, 1916, leaving a widow but no family.

Charles Barrington Brown was born at Cape Breton (Nova Scotia), and educated at Harvard University and at the Royal School of Mines in Jermyn Street. His father, Richard Brown, author of several papers on Cape Breton in the early volumes of our Quarterly Journal, was a close friend of Sir Charles Lyell, and it was through Lyell that the younger Brown was appointed to the Geological Survey of the West Indies (Jamaica) and of British Guiana. The results of this work are contained in valuable reports, written in conjunction with J. G. Sawkins and published in 1869 and 1875. Brown was an explorer as well as a geologist. In 1870 he discovered the famous Kaieteur Falls on the Potaro River in British Guiana, and between 1873 and 1875 he travelled 15,000

miles on the Amazon and its tributaries. Later he was engaged chiefly in the exploitation of gem-stones in Burma, North Carolina, Ceylon, and New South Wales; and in particular his memoir on the rubies of Burma, written in collaboration with Prof. Judd, was an important contribution to the natural history of corundum.

By the testimony of those who knew him best, Barrington Brown's success as an explorer was made possible by personal qualities which endeared him to men of all kinds, and especially by an evident sincerity which caused him to be universally trusted. In his later years he suffered from the effects of fevers contracted during many tropical journeys, but he had reached his seventy-eighth year when he died on February 13th, 1917. He had been a Fellow of this Society since 1879.

Henry Rosales, probably the oldest Fellow on our list, in which his name first appeared in 1877, was well known as a geologist and mining engineer in Victoria for more than sixty years. Born in Spain, he received his training at Freiberg, and went out to Australia, where he was engaged on the Ballarat and other gold-fields of Central Victoria. His first communication to this Society was made in 1855, and he was the author of numerous contributions to mining journals and to the publications of the Geological Survey of Victoria. He also made a valuable collection of minerals, which he presented to the University of Melbourne. Retiring from professional life thirty years ago, he continued to take an interest in geological and mining problems, and retained to the last his keen intellectual faculties. He died at Melbourne in May, 1916, aged 94.

Walter Edward Koch was born on March 19th, 1848, and was educated at Marlborough, at King's College, London, and at St. John's College, Cambridge. He adopted the profession of mining engineer, and for the last thirty years of his life was engaged in mining work in various parts of America. He became a Fellow of this Society in 1869, and, though he did not contribute to our Journal, always preserved his interest in geology as well as chemistry. At the time of his death he had in hand a series of experiments on the effects produced in rocks at high temperatures. He died on May 25th, 1916, at El Paso (Texas), where he was manager of the famous quicksilver-mines of Terlingua.

Frank Fowler, who died on January 16th, 1917, aged 53, was a well-known Government official in British Guiana. There he was born and educated, and his life was spent in the Civil Service of the Colony. At the time of his death he had filled for fourteen years the office of Commissioner of Lands and Mines. He was elected into this Society in 1910.

Charles Dawson, though born in Lancashire, passed most of his life in Sussex. There, while following the profession of solicitor, he found time to gratify his interest in geology and archæology. He devoted much attention to the reptilian remains in the Wealden formation, and made a valuable collection, which is now deposited in the British Museum (Natural History). Later he was attracted to the study of prehistoric man, and his name became widely known in connexion with his discovery of the Piltdown skull. Of this, with Dr. Smith Woodward as coadjutor, he communicated an account to our Society in December, 1912. He died at Lewes, after a protracted illness, on August 10th, 1916. He had been a Fellow of our Society since 1885.

Thomas de Courcy Meade, who died on February 13th, 1916, had held since 1894 the post of City Surveyor at Manchester. There his most important work was done in connexion with the new drainage scheme of the city, on which he read a paper to the Engineering Section of the British Association in 1915. He was elected a Fellow of this Society in 1891, and was also a member of the Institutions both of Civil and of Mechanical Engineers.

Lastly, we have to lament the premature death of five of our younger Fellows, who have fallen while fighting for their country and for the cause of civilization. Reginald Cooksey Burton, Assistant-Superintendent on the Geological Survey of India, attached to the 104th Rifles in Mesopotamia, was wounded in action on April 8th, 1916, and died on the following day, aged 26. During three years of service in India he had done good work, especially in connexion with the gneisses of the Central Provinces and the origin of the Seoni bauxites; and the Director of the Survey describes him as 'one of the most promising, as well as one of the most popular, of its younger members.' Richard Roy Lewer, Lieutenant in the King's Royal Rifles, eldest son of Mr. H. W. Lewer, of Priors, Loughton (Essex), was wounded on

July 15th, 1916, on the Western Front, and died six days later, aged 26. He had already done useful work in the oil-fields of Burma, Russia, and Western Canada. ARCHIBALD WILLIAM ROBERTSON DON, Lieutenant in the Black Watch, fourth son of Mr. R. B. Don, of Tealing House (Forfarshire), died in hospital in Greece on September 11th, 1916, aged 25. The keen interest in Geology which he had shown as an undergraduate at Cambridge was not lost when he quitted the University to enter the medical profession, and his researches on *Parka decipiens* seemed to hold the promise of much good work in the future. JAMES COWIE SIMPSON, Lieutenant in the Royal Engineers, eldest son of the late Mr. Watson Simpson of Edinburgh, was killed in action on December 4th, 1916, aged 31; and RALPH HAWTREY, also a Lieutenant in the Royal Engineers, son of the late Mr. Montagu Hawtrey, of Shanghai, was killed in action on September 3rd, 1916.

SOME ASPECTS OF IGNEOUS ACTION IN BRITAIN.

IT has often been pointed out that, for so small an area, the stratigraphical record in Britain is a remarkably varied one, bearing witness to many vicissitudes of physical conditions in this part of the earth's surface. To this may be attributed in some measure the lead which British workers have so often taken in the development of stratigraphical geology. It is equally true that the record of igneous activity in our area is full and varied to an extent not to be paralleled elsewhere. Whether here also we have always lived up to our privileges I will not now enquire, but it will be granted that in the last quarter of a century, at least, much valuable work has been done in this field. In this revival of interest, shown both on the Geological Survey and among individual workers, we can trace especially the influence of Sir Archibald Geikie. The masterly account of igneous action in Britain, which he gave from this Chair in 1891–92, was expanded subsequently to the compass of two large volumes, but it would to-day need to be much further amplified in order to include the results of later researches. I must be content to choose a single aspect of this large subject, and I propose to consider it from the point of view of the relation between igneous action and crust-movements. The link

connecting these two classes of effects is found in the consideration that both afford relief to the unequal stresses which are continually being set up in the earth's crust by causes regional as well as cosmic.

To enquire into ultimate causes is no part of my design. Mellard Reade showed long ago how mountain-building movements result from prolonged sedimentation in a slowly subsiding geosynclinal basin, but the general problem seems to involve also other factors. There is in the greater orogenic displacements an element of unilateral progression, which leads us to picture them in imagination as gigantic waves. In the broad structure of Europe we see the results of four successive earth-waves of the largest order, all advancing in a general sense from the south. The actual belts of folding, as laid down on a map, show sweeping curves, with a certain amount of interlocking. At one place only do three of these belts come together within a relatively narrow space, and it is precisely in this significant situation that the British Isles lie.

The unique advantages enjoyed by British geologists, to which I have adverted, result then from the fact that three systems of crust-movements, at widely separated epochs, the Lewisian, the Caledonian, and the Hercynian, have all contributed to the building of our country. Moreover, the whole history of Britain can be viewed in relation to these cardinal events, and only when so regarded appears as a coherent sequence. Especially is this true of igneous action, since fluid, or partly fluid, or potentially fluid, rock-material is necessarily more responsive to changes in stress-conditions than the solid crust itself. Accordingly, each great system of crust-movement has been attended by a display of igneous activity, related to it in a manner which clearly bespeaks some underlying law of causation. There is in each case evidence of extensive plutonic intrusion within the disturbed area, either at the crisis of the disturbance, or following it after no long interval by geological reckoning. These copious intrusions of magma, no part of which reached the surface, are not only events of the first magnitude, but seem to differ functionally from the igneous action which characterizes other stages of the cycle. This more diffused activity, taking the form of extrusion as well as intrusion, is developed during the gathering of crustal stress before the critical epoch, and again especially in the later waning stages. It has many features suggesting that the several episodes which can be distinguished have their proper places in an ordered sequence. When there has

been igneous action during a season of relative quiescence, this too has its own significant characteristics.

We shall not, however, appreciate fully the relation between igneous action and crustal stress, unless we have regard also to the petrographical facies of the rocks erupted at different phases of a complete cycle. It is becoming increasingly evident that magmatic differentiation is closely bound up with progressive crystallization, the essential factor being a separation, or partial separation, effected between the crystalline and the fluid portions at one stage or another of the process. Thanks to the researches of the Washington chemists, this doctrine now rests upon a basis of laboratory experiment, and Dr. Bowen has recently put forward a general theory of primary differentiation founded upon this direct evidence. The series of successive 'fractions' begins with terms rich first in magnesian and next in calcic silicates, and shows then a steady increase both in alkalies and in silica. So far this agrees with what has been so often observed in a series of related plutonic intrusions, following one another in an order of increasing acidity with falling temperature. Bowen shows, however, that a rock rich in alkali-felspars and free silica need not represent the final term. The continued concentration of water and other gases in the residual magma gives rise in the later stages to hydrolysis and analogous reactions, by which the progress of crystallization is much modified. This appears in the formation of orthosilicate micas in the presence of free silica, and finally in the production of nepheline and other basic alkaline silicates at the expense of the albite molecule. The differentiation-series is thus extended by the addition of new terms, still increasingly rich in alkali, and specifically in soda, but now with a diminishing content of silica. The empirical law of increasing acidity must therefore be replaced by one of *increasing alkalinity*. An ideal complete series would begin with an ultrabasic type, such as a peridotite, devoid of alkali, and end with another ultrabasic type, such as an ijolite, very rich in alkali.

This doctrine, for which much geological as well as chemical evidence can be adduced, throws an interesting new light upon the mutual relations of igneous rocks. For my present purpose it is sufficient to emphasize the general rule to be deduced from it. If at any stage of progressive crystallization, or progressive fusion, a separation or partial separation is brought about between the fluid and the crystalline part, the former will be relatively rich in alkali, and particularly in soda, while the latter reciprocally will be rich in

lime and magnesia. As regards the mechanism of such separation, Bowen lays stress especially upon the sinking of crystals in a mass which is still mainly liquid. Simple physical considerations, however, tell us that a great liquid or mainly liquid reservoir within the earth's crust can have only a temporary status. It is doubtless incidental to the existence of much more extensive tracts of the lower crust in a semi-liquid state, that is, as a liquid crowded with crystals or a crystalline fabric with interstitial liquid. Such a condition must be postulated beneath any region which is the theatre of long-continued igneous activity, and a mass so constituted possesses remarkable properties. In particular, it is very sensitive to unequally distributed stress, the liquid part tending to be driven from places of greater to places of less stress. When in such a region an unequal distribution of crustal stress is maintained sufficiently long, there will be a continued flux of the interstitial magma, which will be driven out from areas of special disturbance to accumulate beneath areas of relative quiescence. If, in addition to this lateral displacement, the magma works its way into the upper crust or to the surface, highly alkaline rock-types may result. Otherwise, and more generally, the magma so displaced will go to impart a more or less marked richness in alkali to the crust beneath the undisturbed areas, and the effect may be seen only at some later epoch and in a less extreme manifestation.

The doctrine of two classes of igneous rocks, alkaline and calcic, having a significant geographical distribution in relation to the great tectonic features of the globe, has, then, a certain justification. It does not, of course, imply any sharp division; and perhaps the more philosophical conception is that of two opposite petrographical poles, towards which igneous rocks tend as a result of primary differentiation. There is naturally some complication introduced by subsequent processes, giving rise to the great diversity of igneous rocks known to petrographers; and these later processes may sometimes obscure, as regards individual rock-types, the primary characteristics.

To illustrate these general remarks, and to put to the test the element of hypothesis which they contain, I propose to recall rapidly the leading events in the igneous history of the British area. We are met at the outset by a difficulty which arises from lack of full knowledge. There is only one part of the country, namely: the Scottish Highlands, where any large expanse of the

oldest rocks can be seen, and much study of that difficult region has left some fundamental questions still unsettled. It is not yet a matter of common agreement whether the 'Older' Gabbros and Granites of the South-Eastern Highlands belong to the same epoch as the Lewisian of the North-West, or to a distinct and much later epoch.

Leaving this question and others for future solution, we may note meanwhile some very instructive features of these ancient plutonic intrusions. The rocks are of calcic facies, like all other rocks intruded in close connexion with powerful lateral thrust. In this case the connexion is of the closest possible kind. In the South-Eastern Highlands especially it is clearly seen that the earliest intrusions of magma preceded the climax of the disturbance, so that the basic members of this rock-series met the brunt as rocks already solid; while the later and more acid magmas were intruded near the height of the mechanical disturbance, and during its decline. The further circumstance that the region was long maintained at a high temperature had an interesting consequence; for the straining-off process, which I have pictured as taking place in the deeper crust, was here effected at a level which is now exposed to view. How in this way broad fringes of pegmatite have been squeezed out from the half-consolidated granites has been well described by Mr. George Barrow. The pegmatites are often rich in microcline and muscovite, but this is the limit of their approach towards the alkaline pole. It is instructive to compare these Scottish Archæan granites with those which build the great Laurentian batholites of Lower Canada, intruded under very different mechanical conditions. There we find a fringe of albite-granite, albite-syenite, and finally nepheline-syenite and ijolite. The close synchronism of the British Archæan intrusions with powerful lateral thrust finds a parallel, however, in many other parts of the world, and the fact is of prime importance in relation to the crystalline schists. The older sediments were recrystallized under the influence of great stress as well as high temperature, a conjunction not realized on the same extensive scale at any subsequent period.

What has been remarked of the 'Older' plutonic intrusions of the South-Eastern Highlands seems to be true also in the main of the Lewisian series, assigned on the view most widely held to an earlier epoch, and so to an earlier system of crust-movement. Erosion, however, has exposed lower levels in the North-West, and thus has presented us with a different aspect of the igneous economy. In

particular, the more basic members of the series are much more in evidence, as also the invasion of these by the later acid rocks with resultant intermingling and hybridism.

Time does not permit me to do more than mention the Archæan crystalline rocks of North-Western Ireland, of Central Anglesey, of Malvern and the Wrekin, and of the English Channel tract. I pass on to the Dalradian Series, belonging on the more generally accepted view to some time between the Lewisian crust-movements and those to which the 'Older Granites' of the South-Eastern Highlands were related, but on Mr. Barrow's reading older than the one great Archæan system of mountain-building in that region. Whatever may be their chronological relations, it appears that these ancient sediments, now so highly disturbed, were laid down in a basin which was undergoing a slow subsidence but no movement of the nature of folding. This is to be inferred from the extension of the series and the persistence of the same types of sediment over wide areas. Contemporaneous igneous action is indicated, on no great scale, but of very distinctive type. Specially characteristic are the spilite-lavas in the Loch Awe group of Knapdale, with their associated intrusions of albite-dolerite and soda-felsite. If the spilites seen in North Glen Sannox (Arran) are in their original relations, which I see no reason to doubt, they afford evidence of similar eruptions at a lower horizon. The 'pillow-lavas' and associated volcanic rocks of County Tyrone were likewise referred by Sir Archibald Geikie to a Dalradian age, and, although he has retracted this opinion, the materials for a final judgment are still to be gathered. Probably to this age, and certainly to a very early pre-Cambrian epoch, belong the 'Green Rocks' studied by Mr. Greenly in Anglesey and by Dr. Matley on Bardsey and the coast of Lleyn. These reproduce the same characteristic types, both effusive and intrusive.

The oldest volcanic rocks in Britain have, then, a common petrographical facies, and with them are associated intrusive rocks also of certain well-defined types. The chief characteristic of the whole is a richness in sodic felspars. Mr. H. Dewey & Dr. J. S. Flett have shown that the same association of rock-types recurs in the British area at several later epochs, and they consider that it is peculiar to

'districts that have undergone a long-continued and gentle subsidence, with few or slight upward movements, and no important faulting.'

In several parts of Wales and the English Midlands we have evidence of igneous activity at a much later period of pre-Cambrian

history. Although there are no data for correlating the rocks of the isolated areas, it is clear that they all belong to a time when the main Archæan crust-movements were past. It does not follow that the conditions as regards crustal stress were the same in the several districts, and the observed petrographical differences are probably not without significance. In Pembrokeshire there seems to be no noteworthy break between the volcanic series and the succeeding Cambrian, and indeed the basic intrusions which represent the latest igneous episode sometimes penetrate the Lower Cambrian strata. The old lavas and tuffs here have been studied only in part, but soda-rhyolites seem to be the most characteristic type. The associated intrusions in the Brawdy and St. David's districts, as described by Dr. H. H. Thomas & Prof. O. T. Jones, include especially albite-granites, and the plutonic complex of Johnston is also composed of rocks rich in sodic felspars. In this area, not affected by any contemporaneous disturbance, the rocks have, then, a pronounced alkaline facies. Herein they differ from the probably homotaxial rocks of the Wrekin and Malvern, Bangor and Llanberis, areas which lay close to centres of Lewisian intrusion, and were perhaps still under the influence of special stress.

With the Palæozoic era we enter upon a time concerning which we possess much fuller information. Some leading features of the broad structure of our country were already roughly blocked out, and have exerted a dominant influence upon subsequent events. To the north-west was the large crystalline mass of which the Scottish Highlands and North-Western Ireland are relics, consisting of great plutonic cores with their aureole of metamorphosed sediments. This, with a general north-easterly and south-westerly extension, marks roughly one limit of the geosyncline in which our Lower Palæozoic strata were laid down. As regards the southern limit, there are many indications of an important Archæan tract on the site of the English Channel; and it may well be that what we regard as the Armorican trend was already impressed on the southern part of the British area, as the Caledonian trend was on the northern. The geosyncline thus bounded was not a simple one, but contained within it minor features, likewise of Archæan age, which continued to make their influence felt at later times.

During the deposition of the Cambrian and earlier Ordovician sediments this area was undergoing a general subsidence. The downward movement, however, was neither equable in extent nor

uniform in rate, and was at times interrupted and locally reversed. In particular, the Ordovician conditions were ushered in by differential vertical movements, which accentuated the geosynclinal structure, defining more strictly the north-western border, probably the southern too, and developing areas of relative elevation in the interior, which were broadly of the nature of horsts. It was about this time that igneous action was initiated, breaking out in the marginal part of the basin, and affording relief to the differential stresses which there attained their maximum.

Following upon a prolonged gentle subsidence, not complicated by any movements indicative of lateral thrust, these early eruptions had everywhere a pronounced alkaline, that is, sodic, facies. The earliest, which broke out close to the actual borders, all belong to the 'spilitic series' of Dewey & Flett. The predominant basic lavas are typical spilites, and, if acid types occur, they are soda-rhyolites with corresponding tuffs. The associated intrusive rocks are of types constantly found in this connexion, such as albite-dolerites and soda-granite-porphyries. Here comes the volcanic series of which relics are found along the actual Highland Border, especially in Forfarshire and Kincardineshire. The volcanic belt is perhaps prolonged farther south-westwards, for to this series Mr. Gunn has referred the North Glen Sannox spilites and Sir Archibald Geikie the volcanic rocks of Tyrone. In Cornwall the spilites of the Lizard and Gorran Haven seem to preserve relics of a similar train of volcanic centres on the southern border of our area. The age of the eruptions in these several districts cannot always be fixed with precision. They are commonly referred to the Arenig, but on the Highland Border at least they may, according to Dr. Campbell, be Upper Cambrian.

From this narrow border-belt igneous activity shifted to a wider belt lying somewhat within the border. The eruptions here were on a grander scale. Dating from the Arenig, they continued in some districts into part of Llandeilo time. In addition to the spilitic series, the rocks of this submarginal belt include other types, likewise characterized by richness in sodic felspars. Here belong in the north the volcanic districts of the Southern Uplands of Scotland, extending from Girvan and Glenluce to the Muirfoot Hills in Peebleshire, and in the west the Lower Palæozoic inliers of the Lough Mask district, described by Prof. Reynolds & Mr. Gardiner. It may be remarked that the plutonic complex of Girvan consists of calcic types of rocks, and in the Irish district also the associated

intrusive rocks are only in part of strongly sodic nature. The intrusions are of later date than the volcanic outpourings—some in the Lough Mask area are post-Llandovery—and a change in the stress conditions may be presumed. We shall see later that calcic intrusive rocks may be found in closer relation with volcanic rocks of alkaline nature, and that the seeming anomaly is in accordance with the principles laid down.

In the south the submarginal belt of activity includes the volcanic districts of Pembrokeshire, our knowledge of which has been much enlarged in recent years. The lavas of Skomer Island, described by Dr. H. H. Thomas, include a range from soda-rhyolites through various types of soda-trachytes to mugearites and olivine-basalts. To the same series we may probably refer the soda-rhyolites of Trefgarn, near Haverfordwest, and perhaps the volcanic group of Llangynog, near Caermarthen. This is described as consisting of augite-andesites and rhyolites; but the former seem to be of mugearitic rather than andesitic affinities, and so make no exception to the general alkaline facies.

These various occurrences are probably all low down in the Arenig; but those of North Pembrokeshire belong to higher horizons, indicating a progressive displacement of the theatre of activity towards the interior of the geosyncline. The ceratophyres of Abercastle are intercalated in the *Tetragraptus* Beds, while the soda-rhyolites and rhyolite-tuffs of Llanrian are in the upper part of the *Didymograptus-bifidus* Zone, and the fuller development at Fishguard is probably at about the same horizon. Here, in addition to soda-rhyolites, Dr. Cox has recognized typical spilites. They were succeeded by basic intrusions, mostly in the form of irregular sills. In these the strongly alkaline nature is sometimes less pronounced, but the dolerites of Fishguard have an oligoclase-andesine as their dominant felspar, and the thick sills of St. David's Head, probably of the same series, show albitization.

In the interior of the British geosyncline late Cambrian and early Ordovician eruptions were not wholly wanting, but they were on a feeble scale, and were confined to the neighbourhood of areas which had already acquired special tectonic importance. If any outbreak occurred on the borders of the Archæan horst of Anglesey, the evidence of it has been lost. But the Harlech anticline had already declared itself, perhaps as the reassertion of a concealed Archæan centre, and on its skirts the first effects of vulcanism were localized. The lavas in the Upper *Lingula* Flags

of Dolgelly are much albitized, and appear to be spilites. The crystal-tuffs and agglomerates of Rhobell Fawr, immediately underlying the base of the Ordovician, resemble those of the Sanquhar district of Dumfries-shire, and will probably be found likewise to have alkaline affinities. Later came the soda-rhyolites of Dolgelly and Cader Idris, assigned by Mr. P. Lake & Prof. S. H. Reynolds to a Lower or Middle Arenig age, and on the other side of the Harlech dome Prof. O. T. Jones has noted spilite-lavas in the Lower Arenig of the Lleyn.

So far, the only important crust-movements had been of the nature of a slow subsidence. The igneous action connected with the subsidence shows a certain symmetrical disposition relative to the shape of the geosynclinal region, and the general alkaline nature of the igneous rocks is significant in the same sense. Towards the close of the Arenig age, however, a change in all these conditions begins to be evident. It is clearly related to the coming in of a certain element of lateral thrust, a premonition of that which attained a much greater intensity at a later time. The symmetry of arrangement gave place to a decided unilateral disposition. By the accentuation of old features and the development of some new ones, the original geosyncline came to be divided into areas which can for many purposes be considered separately, and in each of them the unilateral factor, related to a thrust coming from the south or south-east, is apparent. The vigorous outbreak of igneous activity which ensued was comprised mainly in Llandeilo time, and its products are found to differ significantly from those of the earlier eruptions, the spilitic series giving way largely to the andesitic.

I will consider especially the Welsh part of the region, since there our information is relatively full. It was in some measure isolated by the presence, on what may be termed its 'lee side,' of the old massif of Anglesey. In front of this, as we now see it, and having the same north-easterly and south-westerly direction, are the two parallel ridges in which the younger pre-Cambrian rocks emerge, one extending from Bangor to Caernarvon and the other passing near Llanberis. The initiation of these ridges seems to have been an early consequence of the slowly gathering thrust, and they played the part of outworks to the Anglesey barrier. A broader uplift, with the same Caledonian trend, was developed through Shropshire and Radnorshire, and, though too gentle an undulation to act as a buttress, probably had its influence on the distribution of eruptions in the area.

The widespread vulcanicity of Arenig times in South Wales had died out, and the new theatre of activity lay farther north. Eruptions broke out on the flanks of the new central anticline, both in Radnorshire and in Shropshire. In Merioneth the vulcanicity, prolonged through the whole of Llandeilo time, was on a larger scale. It is represented by a great thickness of fragmental accumulations, together with andesitic sills which, as Prof. Fearnsides has shown, were closely bound up with the volcanic episode. In Caernarvonshire, in addition to explosive outbursts, there was a great outpouring of lavas. The district there affected, centreing in Snowdonia, extends in one direction beyond Conwy and in the other into the Lleyn peninsula. The maximum energy of this age in Wales was thus displayed along a belt immediately fronting the Llanberis ridge; but at that boundary it came abruptly to a stop.

The several volcanic districts show nearly the same petrographical types, following one another in the same order of decreasing basicity, but with significant points of difference. In the Wells district of Radnorshire basalts were succeeded by hypersthene-andesites, and these finally by rhyolites. About Arenig Fawr, in Merioneth, the earliest term of this sequence is wanting. First come agglomerates and tuffs of hypersthene-andesite composition, then, after an interval, more acid andesitic material, followed by dacitic and finally rhyolitic. In Snowdonia, not merely are basalts lacking, but pyroxene-andesites are only feebly represented. The great pile of lavas, with subordinate tuffs, is first dacitic and then rhyolitic in composition, reaching also a higher degree of acidity than is found elsewhere. The earlier types of the sequence are thus better represented in the south, and the later in the north. In the Shropshire district, lying somewhat aside from the main line of thrust, the volcanic record is much scantier, and is also spread over a longer time. After the Stapeley andesitic ashes, which seem to correspond with the lowest group of Arenig Fawr, the Llandeilo strata here show no sign of contemporaneous vulcanicity, and the completion of the sequence is represented in the Bala Series by the Hagley and Whittery ashes, the admixture of rhyolitic with andesitic material in the latter marking the final phase.

The change from an alkaline to a calcic facies, which marked the Llandeilo epoch, did not necessarily take effect simultaneously in different areas. In the Cader Idris district the spilitic type seems to have persisted while andesitic eruptions were breaking out

elsewhere, for Dr. Cox has recognized as spilites the thick group of lavas which forms the summit of the mountain, and with these may probably be connected the intrusive sill of soda-granophyre which makes so prominent a feature.

The intercalation in the volcanic sequence of sills which were intruded almost contemporaneously is a noteworthy characteristic of Ordovician vulcanicity, whether of alkaline or of calcic facies. It is illustrated by sills of ceratophyre at Abercastle and perhaps of spilite on Mullion Island, but also by hypersthene-andesites in the Arenig hills and Shropshire and by rhyolites in the Lleyn district. Again, some plug-like intrusions breaking through the Cambrian of Caernarvonshire not improbably mark the sites of Llandeilian volcanoes. With these exceptions the very numerous intrusions in the Welsh area are later than all the volcanic eruptions. Of a distinct plutonic phase of activity there is but slight indication, and that only in the north-west, the diorite-granite complex of Sarn being the chief representative.

The minor intrusions are found in all the districts, but on the whole in greater force as we pass towards the north or north-west, and this is especially evident in the case of the acid rocks. Moreover, in this direction—that of increasing stress—the concordant habit gives place more and more to the transgressive. The intrusions, like the volcanic outbreaks, are sharply limited by the line of the Llanberis ridge. The small Llanfaglen mass, if it belongs to this age, is the only exception. The succession of different types, in so far as it can be ascertained, is one of increasing basicity. Some of the latest intrusions are proved in Shropshire to invade the *Pentamerus* Limestone of the Llandovery Series. Elsewhere the numerous intrusions of dolerite are intercalated in the main volcanic group and at lower horizons, but they must certainly be referred to a late date. While affecting the sill habit, they do not make sills with any great lateral extension, but tend to occur along anticlinal and synclinal axes. We may infer that they were injected at a time when folding of the strata was already beginning, namely: that folding which culminated towards the close of the Silurian in the main Caledonian crust-movements.

Next to Wales the most important area of Ordovician igneous activity is the English Lake District. Both here and in the neighbouring inlier of Edenside early eruptions are represented by a few thin lavas and tuffs in the upper part of the Skiddaw Slates. The rocks, which are much altered, have been described

as andesites, but their felspars can often be identified as oligoclase, and one type in the Knock district is a characteristic spilite. The much more important eruptions, which came later, lasted without apparent interruption through Llandeilo time, and continued into the Bala. The sequence, as set forth by my colleague, Dr. Marr, is less simple than that seen in Wales. Pyroxene-andesite lavas were followed by a much more widespread outpouring of basalts, and then by activity of the explosive type, which produced a great thickness of breccias and ashes. Many of these show a commingling of basic and acid material. To this succeeded a second group of pyroxene-andesites, and finally rhyolitic lavas and breccias, which are in part interstratified in the Coniston Limestone Group.

No distinct plutonic phase of this age is to be recognized in the Lake District, but the intrusions which followed the volcanic outburst were numerous and of various petrographical types. The largest masses, such as that of Ennerdale and Buttermere, are of acid nature, sometimes with basic rocks involved in their marginal parts. There is no conspicuous group of dolerite sills, but many of the intrusions, ranging from acid to ultrabasic in composition, have assumed an irregular sill-habit. The most basic occur in the Skiddaw Slates and the most acid in the Coniston Limestone Group, suggesting a vertical distribution in accordance with density. The whole suite of rocks, volcanic and intrusive, excepting the early sodic types, has a calcic facies. In this connexion the frequent occurrence of red garnet is worthy of remark, and, whether of primary or of metamorphic origin, its chemical significance is the same. The general geological relations are much less clearly revealed than in Wales; but it is probable that here too we are to recognize in the Llandeilian igneous action the influence of a certain element of lateral thrust directed towards the north or north-north-west. It is in that direction that the large acid intrusions are situated. We can verify that at a later epoch, when the rocks were folded, overthrust, and cleaved by a more intense thrust on the same lines, these large igneous masses, perhaps larger than their exposures indicate, acted in some measure as a buttress. Whether their resistance was backed by an old ridge concealed beneath the Skiddaw anticline, we do not know, but the existence of such an ancient barrier would explain the absence of intrusions on the farther side of that line.

It does not appear that the principal volcanic series of Wales and

the Lake District is represented in the Southern Uplands of Scotland, although local unconformity indicates some crust-movement in that area at about the same time. Such vulcanicity as the Llandeilo there shows seems to have been merely the continuation of the Arenig outbreak. In Ireland early Ordovician eruptions appear to have been confined to the marginal parts of the area. As regards the interior, there are records of igneous rocks assigned to the Llandeilo and Bala at numerous places from County Down to the coast of Waterford; but our knowledge, both on the stratigraphical side and on the petrographical, is still so imperfect that general conclusions would have but little value.

During the Bala and part of Silurian time there was renewed subsidence, affecting more or less the whole of the area, but a complete restoration of the early Ordovician conditions was not now possible. Crustal stress, not wholly relieved by the Llandeilian vulcanicity, was doubtless unevenly distributed, and was undergoing change. We find accordingly that igneous activity during this time was feeble and sporadic, and showed no common characteristics of the petrographical kind, though a reversion, or partial reversion, to sodic types is often noticeable. Setting aside such areas as the Shelve district and that of the English Lakes, where Llandeilian vulcanicity was prolonged into Bala time, there were revivals during the latter age at a number of isolated centres. In the Southern Uplands there was an outbreak in the neighbourhood of Peebles, the lavas being now of acid instead of basic nature, but still of sodic types. In the Berwyns again the alkaline nature of the Bala igneous rocks is unmistakable; but in some other cases, such as the neighbouring Breidden Hills and the Kildare inlier in Ireland, the petrographical facies is not clearly characterized. These Bala revivals, if we except that of Peeblesshire, were all in the interior of the area, but the scattered outbreaks in the Silurian occurred in the marginal belt, those assigned to the Upper Llandovery being in the neighbourhood of the Bristol Channel. Of these the Mendip and Tortworth lavas, although described as andesites, seem to be of somewhat alkaline composition, and the same may be true of the basic lavas with 'pillow-structure' at Milford Haven. The latest volcanic rocks of this suite, seen at Clogher Head in the far west of Ireland, are mainly of acid type.

The most highly alkaline of our Lower Palæozoic igneous rocks, those of the Assynt district, I have perforce omitted. The

stratiform habit of the plutonic complex, and of its component parts, and the regular sill-form of its satellites assure us that the intrusions were effected during a time of relative repose; but, as regards their age, we know only that they are younger than the Durness limestones and older than the Caledonian overthrusting. The lack of stricter chronological data and the isolated situation of the district preclude any present discussion of the relations of this interesting group.

Towards the close of Silurian time the original geosyncline had been filled in. and indeed was being replaced by a geanticline. The thrust, which had been renewed, now attained a much greater intensity, until it culminated in the main Caledonian crust-movements. The rocks yielded by folding, or cleavage, or overthrust, according to their lithological characters; but, allowing for this, we see that the effects become more marked, both in separate areas such as Wales and the Lake District and in the region as a whole, when we pass northwards or north-westwards. The climax is reached where the front of the great Highland barrier itself has broken before the advancing earth-wave. Those parts which had experienced to the full the effects of the Archæan metamorphism and had cores of Archæan plutonic rocks, could yield only *en bloc*. The movement, therefore, instead of being distributed, was localized in great dislocations along what Mr. Barrow styles the 'outer margin of crystallization.' The displacement at the Highland Border seems to be of the nature of an underthrust; a second master-fracture is represented by the line of the Great Glen; and a third by the Moine overthrust, or by the system of which it is the chief member. The south-westward convergence of these three lines shows how the earth-wave, travelling on the whole northwards, was swung round on meeting an obstacle with a north-easterly and south-westerly trend. The effect of these displacements was to sever the Highland tract from the Lowlands, and to divide it into three broad belts, South-Eastern, Central, and North-Western, each narrowing somewhat in the south-westerly direction.

The Caledonian crust-movements were not immediately accompanied, like those of Archæan age, by igneous action. The system of intrusions known to Highland geologists as the 'Newer Granites,' with others of like age elsewhere in Britain, came somewhat later, after crustal stresses had greatly relaxed. Accordingly,

instead of fringing out into innumerable sheets and veins, they have made large compact bodies. In general the intrusions have avoided the neighbourhood of the great overthrusts, and are to be found chiefly in the interior of those belts of country which had behaved as tectonic units. Thus in the South-Eastern Highlands a train of plutonic masses extends from Peterhead into Argyllshire, and in the Central Highlands a somewhat less important train can be traced from the borders of Caithness to the Ross of Mull. In each case the intrusions are largest and most numerous towards the north-east, where the overthrusting had been least, and the individual masses tend to have their long axes in the common direction. All these facts go to show that, although the great crust-movements were past, the intrusions were localized and guided by a distribution of stress of the same general character.

In Northern Ireland the plutonic masses of Slieve Gallion, Pomeroy, and perhaps others, seem to carry on in a general way the line of the Newer Granites of the Highlands. Farther south a parallel belt of intrusion, referred with some confidence to this age, is represented by the Galloway granites and those of Castlewellan, Newry, and Crossdoney in Ireland. Another belt, including the English Lake District, the Isle of Man, and the long tract of the Leinster granites, seems to mark the limit in this direction of important Caledonian intrusions. In this bordering belt, removed from the principal theatre of disturbance, the abrupt boss-form tends to be replaced by a roughly stratiform habit, as is clearly indicated by the underlying position of the Skiddaw, Eskdale, and Foxdale granites. Even here, however, contemporaneous stress is proved by a certain horizontal differentiation, seen in an increasing acidity and richness in white mica towards the northern edge of each mass. The Leinster granite-tract is more complex, and seems to be the result of several intrusions. The granites of the main chain are foliated and sometimes crushed in a manner which indicates stress during and after their consolidation.

On the petrographical side there are some significant facts of distribution. The name 'Newer Granites' does not adequately describe an assemblage of types which ranges from acid to ultrabasic. In the Highlands, and especially in the large masses situated towards the north-east, different rocks are often intimately associated in a complex which may include peridotites,

diorites, quartz-diorites, and hornblende- and biotite-granites. In this area, presumably near the principal focus of intrusion, the more basic types are often well represented; but farther away, in Galloway, the Lake District, and Leinster, they are either lacking or of small importance. On the other hand, muscovite-bearing granites, which are little in evidence in the Highlands, become the dominant type in the most outlying belt. In Leinster we find granites rich in microcline and muscovite. Here, too, south-east of the main chain, and, as Prof. W. J. Sollas has shown, of somewhat later intrusion, is a group of soda-granites, including some rich in albite. Some of the minor intrusions presumably related to the granites are of thoroughly alkaline composition, and it is clearly suggested that we touch here the limit of the distinctively calcic province which goes with the Caledonian disturbance.

The minor intrusions of the region in general, usually taking the form of dykes, belong to simple petrographical types. There are first porphyrites, perhaps not differing materially in composition from the average magma of the region, and then lamprophyres with their complementary acid rocks. The distribution of stress during a dyke-phase is necessarily more complex than during the preceding plutonic phase. It is compounded of the regional system together with local stresses centreing in the plutonic intrusions, at least when these have the boss-habit. In the areas of maximum disturbance the regional element is usually dominant, but in outlying districts the local stresses prevail. Thus the Caledonian dykes in the South-Eastern Highlands tend to have the strike-direction, and those in Galloway the direction of dip; but round the Shap granite the dykes have a markedly radiate arrangement.

A great system of crust-movement is not completed at one defined epoch. It appears indeed that some part of the Caledonian overthrusting in the Highlands was effected during Old Red Sandstone times: but, what is most in evidence during this waning phase is not the lateral displacement, so much as the differential vertical movement which went with it. Broad folds were gradually formed, in the troughs of which the Old Red Sandstone was deposited. The conditions during this period, and especially the manner in which the vulcanicity was related to the broad geographical features, have been so well described by Sir Archibald Geikie that a brief summary will suffice here. The

principal trough was what is often called the Midland Valley of Scotland, that is, the lowland tract, some 50 miles broad, which divides the Highlands from the Southern Uplands. Subsidence of this area, with correlative elevation of the contiguous tracts, continued through Old Red Sandstone times, and eventually passed into important trough-faulting. It was along the two opposite borders of the depressed area, where differential stress reached its maximum, that volcanic eruption broke out. It began, as Dr. Campbell has proved at Stonehaven, in the Downtonian, but belongs in the main to the Lower Old Red Sandstone. On the north-western side, where activity was most vigorous, it affected a stretch of country which, including its prolongation into Ireland, has a length of about 300 miles. Of the other detached or semi-detached areas of depression the most important are the Lorne and Glencoe district on one side and the Cheviot district on the other. In the far north two or more minor volcanic centres are indicated in the Orkneys and Shetlands, while smaller outbreaks in the Killarney district and in County Waterford mark perhaps the limit of volcanic action towards the west and south.

In these subsidiary basins the linear trough-form was much less pronounced, and a marginal arrangement of volcanic vents is not clearly discernible. None the less, the intimate relation between igneous action and crustal displacement is very apparent. It is illustrated in the most striking fashion by the cauldron-subsidence of Glencoe with its accompanying outflow of lavas, as described by Dr. Clough, Mr. Maufe, & Mr. Bailey. The plutonic phase which succeeded, not in the Midland Valley but in Lorne, Cheviot, and the Shetlands, tells the same story. In each area the plutonic rocks have broken through as abrupt bosses in the midst of the volcanic outpourings; and the cylindrical plugs of Beinn Cruachan and Beinn Nevis, associated with a peculiar piston-like faulting, are the analogues in this phase of the neighbouring Glencoe subsidence. The numerous dykes clustered round these two centres present a sheaf-like arrangement about a north-easterly and south-westerly axis, showing the regional stress modified in some degree by the local. In each case there is a second, inner plug of granite, younger than the majority of the dykes, implying a duplication or alternation of the plutonic phase and that of minor intrusions. In the Cheviot district stress of the regional type was of little moment during the final phase, for the dykes about that centre approximate to a regular radiate disposition.

The volcanic rocks of the Lower Old Red Sandstone belong everywhere to the andesitic series, ranging from basalts to rhyolites, but with pyroxene-andesites as the dominant types. No general law of sequence is apparent. The plutonic rocks are mostly granites and quartz-diorites, tending, however, in Argyllshire to monzonitic types. The dyke-rocks are comparable with those found as satellites of the Newer Granites, and the petrographical characters of the suite as a whole show that the influence of the Caledonian disturbance was still felt. It is to be regretted that we possess no detailed petrographical knowledge concerning the feeble and sporadic revival of vulcanicity in Upper Old Red Sandstone time, when this influence was presumably exhausted. The record of this episode is preserved in Caithness and the Orkneys, in Arran, and in the neighbourhood of Limerick, and the rocks of the first-named district are, according to Dr. Flett, basalts of alkaline affinities.

Setting aside these scattered outbreaks, the next important manifestation of igneous activity in Northern Britain began early in Carboniferous time. The conditions were now wholly changed. All folding related to lateral thrust had long ceased, and a general subsidence was in progress. The change was reflected in the composition of the igneous magmas now brought into action, which were of an alkaline character, at first but moderately pronounced though becoming progressively stronger.

The subsidence was not uniform, and the vulcanicity related to it had a distribution sufficiently significant. The chief theatre of activity was the Midland Valley of Scotland, prolonged to what is now the Mull of Kintyre; and the Carboniferous lavas and tuffs are thus found in close proximity to the very different volcanic rocks of Old Red Sandstone age along the borders of the same tract. Another volcanic belt was situated on the other side of the Southern Uplands, corresponding roughly with the axis of the Old Red Sandstone basin of Cheviot. There were also more isolated centres of activity, one as far away as Limerick; but I shall deal with the matter briefly, taking the Midland Valley as a typical area.

One point of interest brought out by the detailed mapping is the gradual shifting of the theatre of activity, in general from east to west. In the east volcanic rocks are practically confined to the Calciferous Sandstone Series, and later igneous action took the form

of intrusion; but in West Lothian, West Fife, and Stirlingshire important volcanic groups appear in the Carboniferous Limestone Series, and farther west vulcanicity continued in some districts into the Upper Carboniferous. In the course of the revised survey of the ground Dr. Flett, Mr. Barrow, and Mr. Bailey have added much to our knowledge on the petrographical side. The volcanic rocks are mostly of basic composition. Not every type of basalt bears the evident mark of richness in soda, but their constant association with mugearites and trachytes is always significant. Intercalated among the lavas, with corresponding tuffs and agglomerates, the same types occur in the form of sills, which must have been intruded during the volcanic period. Sills and dykes of later intrusion belong to other petrographical types with more strongly marked alkaline characters. They include phonolites, analcime-dolerites, essexites, teschenites, and picrites, and in smaller occurrences analcime-basalts, monchiquites, and limburgites.

In the eastern districts these alkaline rocks were apparently intruded in Carboniferous Limestone times. Similar intrusions in the west may be in part of like age, but some in Ayrshire are found in strata as high in the succession as the latest Carboniferous, if not higher. Further, these Ayrshire intrusions, or some of them, are younger than, and evidently related to, the volcanic group of the Mauchline basin, interstratified among red sandstones which were assigned by Sir Archibald Geikie to the Permian. Whether of Permian or of uppermost Carboniferous age, this interesting volcanic outbreak is to be regarded as a pendant to the Carboniferous igneous activity of the area. As described by Mr. G. W. Tyrrell, the Mauchline lavas are all of very basic composition, and include olivine-basalts, sometimes approximating to limburgite, analcime-basalts and monchiquites, and fresh nepheline-basalts. The intrusive rocks, besides essexites, teschenites, and picrites, comprise a number of peculiar types very rich in nepheline or in primary analcime. The group as a whole marks the final stage of the increasing alkalinity of the Carboniferous suite.

Of the Thornhill volcanic rocks, in Dumfries-shire, which Sir Archibald Geikie correlates with the Mauchline group, we have as yet no petrographical account; but in the numerous small volcanic necks, with associated dykes and plugs, on the coast of Fife, also assigned to the Permian, there are monchiquites and nepheline-basalts closely comparable with those of Ayrshire. It is not improbable too that at this late Palaeozoic epoch diffused igneous

activity attained a wide extension through the Highlands. Scattered dykes of the same distinctive types as those of the Ayrshire district are found in the isles and littoral of Argyllshire, in the Glasgow district, Central Ross, Eastern Sutherland, and the Orkneys, and volcanic necks on the north-eastern coast of Caithness reproduce all the characteristics of those of East Fife.

Of more doubtful significance are the east-and-west dykes of quartz-dolerite and tholeiite, which are scattered over the southern half of Scotland and across the Border. They were intruded in relation with the faulting of the country at or near the end of the Carboniferous Period. Closely connected with them in the Midland Valley of Scotland are numerous large sills of quartz-dolerite, sometimes accompanied by granophyre; and to the same group we may assign, not only the Whin Sill of Teesdale, but probably the Tynemouth dyke and perhaps the intrusions of Carrock Fell.[1] Quartz-dolerite, though not itself an alkaline rock, has been claimed by Mr. Dewey & Dr. Flett for their 'spilitic' series,' and may possibly sustain a complementary relation towards the types rich in soda; but more light on the question is needed before we can assign to this group of intrusions its part in the Carboniferous system of igneous activity.

If now we glance back at the history of our area during Palæozoic times, it appears, from the point of view that I have tried to suggest, as one complete cycle of events. The culminating episode is that of the principal Caledonian crust-movements, to which the preceding events led up, while the succeeding can be regarded as their natural sequel. That epoch marks the logical dividing-point between Lower Palæozoic and Upper Palæozoic time. Igneous action was an essential factor at numerous stages of the cycle, but it assumed different phases and contrasted characters in accordance with the changing stress-conditions. In particular, we observe how, during the tranquil subsidence with which the cycle began and ended, the magmas extruded and intruded were invariably of alkaline nature, but calcic magmas took their place at all times of special stress. Besides the great system of plutonic intrusions which followed the main disturbance, the Palæozoic cycle included three minor igneous cycles, the Ordovician, the Lower Old

[1] The quartz-dolerites of Haweswater and other parts of the Lake District are older than the Caledonian crust-movements.

Red Sandstone, and the Carboniferous. Of these the second was calcic and the third alkaline, while the first, as a result of the premonitory disturbance in mid-Ordovician time, partook of both characters in turn.

Other points of difference may be noted. The Lower Old Red Sandstone cycle, which was most closely bound up with the operation of lateral thrust, illustrates a well-defined type of igneous action. All manifestations were localized within certain areas, having a definite relation to contemporaneous folding. Explosive outbursts and the extravasation of lavas constituted the first phase of activity; then came the intrusion of plutonic rocks in the form of bosses; and finally, if we disregard exceptional overlapping, the injection of large numbers of dykes and sheets. In the volcanic phase lavas of different kinds were poured out from neighbouring centres. The plutonic rocks broke through in the midst of the several volcanic districts, and sometimes in places already marked out in the volcanic phase. The minor inclusions clustered about the plutonic centres, and tended to orient themselves with reference to those centres. In the earlier and later igneous cycles this orderly disposition is not seen: there were no fixed foci of activity, the theatre of operations shifting from one district to another. The plutonic phase was scarcely represented in the Ordovician and wanting in the Carboniferous Period. With this there went a certain confusion between the extrusive and the intrusive phases, shown by the frequent interpolation of quasi-contemporaneous sill-intrusions in the volcanic succession.

In most of the history that I have briefly outlined Southern England bore no part. Lying outside the region principally affected by the Caledonian disturbance, this area presents so far a much less eventful record. After the early Ordovician activity had passed away from the border belt, there followed here a long season of quiescence; and, when vulcanicity again broke out, its petrographical facies was unchanged. The Upper Devonian lavas of North Cornwall and South Devon are spilites, together with some soda-rhyolites in the Dartmoor district, and the associated intrusions are mostly of albitized dolerites, with more basic types, minverites and peridotites. Further, when another revival of activity took place in the time of the Lower Culm, alkaline types, including spilites, recurred once more.

It is interesting to remark that, during the earlier half of the

Carboniferous, two petrographical provinces existed in Britain, both of alkaline facies but with different histories. The southern one was an old-established province, and preserved the spilitic character which seems to be associated with prolonged gentle subsidence. The northern province was a new one, representing a reaction from the Caledonian calcic régime, to which it was genetically complementary. With this character there goes naturally a wider diversity of petrographical types, showing progressive enrichment in soda. The Irish districts of Philipstown and Limerick are clearly related to Scotland, and the same is true of the scanty development in the Isle of Man. The lavas of Derbyshire and of North Somerset, as described by Mr. H. C. Sargent and Prof. S. H. Reynolds respectively, present transitional characters. The occurrence of basalts and of certain types rich in potash would attach these two districts to the northern province; but the Derbyshire rocks seem also to have certain affinities with the Cornish, and those of Somerset include typical spilites.

In Northern Britain igneous activity lingered, as we have seen, into the Permian. In the south it died out earlier, and here the relative repose of the country was at length broken by the advance of the Hercynian or Armorican crust-movements. Although these were felt in some degree over a larger area of Britain, the extreme effects—violent folding, cleavage, and overthrusting—are confined to the south. Of the Caledonian zone of folding the full width had been comprised within the limits of Britain, but it was only the front of the Hercynian earth-wave that invaded our area. The record of igneous activity related to this system is correspondingly scanty. It includes first and foremost the intrusion of the granites of Cornwall and Devon, which are found along a belt running from Scilly to Dartmoor, with possible further extension in both directions.

The great Caledonian intrusions of the Highlands had followed the principal movements after a decided interval, though not late enough to escape all effects of crushing. In the case of our Hercynian granites the interval seems to have been longer. The cleavage and overthrusting of the older strata were long past, and the disturbance had subsided into folding of a gentler type. It is well known that posthumous folding on the same roughly east-and-west axes affected Mesozoic strata at a much later epoch; and it is probably by no mere coincidence that the Land's End and Carn

Menelez granites are situated on the prolongation of the axis of Bray, the Dartmoor granite on the Purbeck axis, and the Lundy granite on the axis of North Devon. Under such mechanical conditions intrusion did not assume the most boldly transgressive habit. The form of any individual mass, in so far as it is revealed, presents a gently domed upper surface, though with steeply sloping sides.

The main Hercynian zone of plutonic intrusion, extending from Britanny eastwards into Central Europe, presents a wide diversity of calcic rock-types, ranging, for example, in the Harz district itself from peridotite to granite; but only the latest and most acid differentiate from the primitive magma penetrated into the northern fringe of the region, and is represented by the Cornish granites, rich in alkali-felspars, and containing abundant light as well as dark mica. The gaseous constituents, in which this granitic magma was peculiarly rich, were eventually driven farther still, and seem to have permeated the country over a wide extent. To pneumatolytic operations connected with this invasion we owe the mineral wealth, not only of Cornwall, but probably, as Dr. A. M. Finlayson has maintained, of other mining districts much farther north.

The observed pneumatolytic effects in Cornwall were not immediately connected with the intrusion of the granite, but belonged rather to the succeeding dyke-phase. As is well known, the fissures occupied by the principal lodes follow the general direction of the strike, while the 'cross-courses' intersect them at right angles, and often shift them. The two sets of fractures and displacement clearly represent successive stages in the relief of crustal stress and the establishment of equilibrium. Of the two complementary groups of dykes the quartz-porphyries, often themselves modified by pneumatolysis, have the same roughly east-and-west bearing as the principal lodes, while the lamprophyres tend to run north and south like the 'cross-courses.'

Owing to the incompleteness of the Hercynian record in Britain, the next manifestation of igneous action, coming after a long hiatus, appears as an isolated episode. The evidence of it is seen in the lower part of the New Red Sandstone succession, which rests with discordance upon the folded Devonian and Carboniferous strata. Whether Permian or Triassic, a question not yet finally resolved, these younger strata belong to a time when folding had wholly ceased, and a new movement had set in, which was of the nature of a local subsidence. As seen in the Exeter district, the volcanic

rocks include feeble flows of lava at several horizons, together with thick bedded breccias composed in part of like materials. The lavas are of various types, and seem to have followed one another in order of decreasing basicity. There are olivine-basalts containing orthoclase, rocks intermediate between these and olivine-trachytes, and again trachytes without olivine but rich in biotite and approximating to the minette and euselite types. The series may be carried farther if we include the rocks of Cawsand and Withnoe, near Plymouth Sound: the one a biotite-trachyte and the other, which has intrusive relations, a quartz-porphyry in which the felspar is almost wholly orthoclase. Here then is a well-marked series of rocks of strongly alkaline nature, rich not in soda but in potash. Sir Jethro Teall has compared them with some of the Permian lavas of the Continent, but in British petrography they are unique. The origin of highly potassic rocks in general is a problem upon which more light is needed, but it could not be profitably discussed in connexion with this isolated occurrence.

Throughout the European area the time during which the Mesozoic strata were laid down, though marked by many vicissitudes, was not interrupted by any crustal disturbance of an accentuated type. At a later epoch all Southern Europe was involved in the Alpine crust-movements, with attendant consequences which are not yet exhausted. Some outlying ripples of this system reached the British area, but there was no igneous outbreak in this country which can be probably related to those events. Tertiary igneous action in Britain has a different significance, and its seat was not in the south but in the north and north-west. Affecting an area of which the northern half of Britain is but a small fraction, this immense and widespread activity was not connected with any lateral creep of the earth's crust, nor did it coincide with mere slow subsidence within the limits of geosynclinal troughs. Its relations seem to be with movements of a larger order. If we follow Marcel Bertrand, we may connect this extra-Alpine Tertiary igneous activity with the foundering of extensive tracts in the Atlantic region, a deepening of an oceanic basin which was itself of no great geological antiquity. It is clear at least that the important movements in this region were differential movements in the vertical sense, expressed by normal faulting instead of folding, and therefore in their tectonic effects plateau-building rather than mountain-building.

The igneous manifestations were closely connected with these vertical displacements, and the manner in which the uprise of molten magma seems to be correlated with the sinking of faulted blocks of country suggests that hydrostatic equilibrium was an important factor in the process. In the British area the maximum activity was developed within a sunken tract lying between the ancient rocks of the Long Island on the one hand and the mainland of Scotland on the other. Such a trough, however, is in no wise comparable with that, for instance, of the Midland Valley of Scotland in Carboniferous times, for it does not bear any ascertainable relation to the geological structure of the country which it traverses. It is an 'Atlantic,' as contrasted with a 'Pacific' feature. Moreover, in respect of the more important events in the igneous record, this area was merely part of a vast region affected by the same activity.

These events characterized by a regional extension may be summarized as: first, the outpouring of enormous quantities of lava; second, the intrusion of innumerable sills; and, third, the injection of a great system of dykes. The lavas, which can be assigned to an Eocene age, did not emanate from great central volcanoes, but, as Sir Archibald Geikie has shown, welled up through innumerable fissures. The individual flows were not large, but collectively they covered a very extensive region. Indeed, for any evidence to the contrary, a continuous lava-field may have stretched from Antrim to beyond Franz Josef Land, a distance of 2,000 miles. The free opening of so many fissures may be taken as proof that there was at this time no crustal stress involving the element of lateral pressure. The same conclusion may be drawn from the behaviour of the sills which followed, remarkable for their regularity and often of wide extent. Vertical movement was doubtless renewed from time to time, for both lavas and sills are intersected by considerable faults. Lava-flows and sills were fed by dykes, but in addition there is a great profusion of dykes of later age. Distributed over a large part of Britain, they maintain a common direction, which seldom deviates far from north-west and south-east, and show a total disregard for the structure of the country which they traverse. Clearly, their intrusion was controlled by some larger law.

Petrographically these extrusions and intrusions are characterized by an overwhelming preponderance of basic types, with an alkaline tendency which is sometimes rather latent than expressed, but

sometimes strongly marked. These Tertiary rocks as a whole have much in common with the Lower Carboniferous igneous rocks of the Midland Valley. Various types of Carboniferous basalts and dolerites are closely reproduced, in addition to the very significant mugearites. Trachytes are less prominent, but are found in Skye, Ardnamurchan, and perhaps elsewhere. In considering the widely distributed amygdaloidal basalts, it is to be remembered that the contents of the vesicles are an integral part of the rock. It is, then, of interest to observe that the Tertiary and Carboniferous lavas are the chief source in Britain of zeolites, while the very different lavas of the Old Red Sandstone are the home of agates and onyxes. In not a few of the Tertiary rocks primary zeolites, chiefly but not exclusively analcime, make part of the general fabric, and this is true of lavas, sills, and dykes. Another index of an alkaline composition is the incoming of a pleochroic titaniferous augite.

In addition to the Tertiary crust-movements already noticed, of simple type and having a vast extension, there were within the same region disturbances of a different order, strongly accentuated and strictly localized about distinct centres. With these is closely related another series of igneous rocks, chiefly in the form of plutonic masses with a host of minor intrusions as satellites. The principal centres are in the tract, already mentioned, which embraces the Inner Hebrides and the Clyde Isles, and the most remarkable of all is the Mull centre, situated in the middle of that tract. The relations here recall those at the Old Red Sandstone centres of the West Highlands, but show a much higher degree of complexity. They have been unravelled by the labours of the Geological Survey, and the map of the district, with the accompanying memoir, will doubtless add largely to our knowledge of the mechanism of igneous intrusion. Pending the publication of that work, I will pass over the subject with a few words.

The special centres were already marked out in the volcanic phase, or even earlier. In Mull there was a cauldron-subsidence, accompanied by outpourings of 'pillow-lavas' and later a girdle of volcanic vents. The great volcanic vent of Kilchrist in Skye and that of Central Arran also belong to an early date, and may have something of the same significance. At subsequent epochs the vertical movement at the special centres, though not always in the same sense, seems to have been in general one of elevation. Where the local movements were strongly emphasized, the plutonic intrusions are sharply transgressive, and they stand in evident relation

to special tectonic features such as ring-like faults and folds. At centres where the disturbance was of a less violent kind there is a tendency to a laccolitic or roughly stratiform habit. Of the minor intrusions the most remarkable are the groups of inclined sheets, dipping inward at angles up to 45°. Such sheets are very numerous in the Cuillin Hills of Skye, and are represented in less force about the centres of Rum and Ardnamurchan. In Mull they occur in extraordinary numbers, and are disposed about two neighbouring points. About some of the plutonic centres there are local groups of dykes with a radiate arrangement; or, again, the dykes of the regional series become unusually numerous, and are drawn into a sheaf-like disposition. In all these phenomena we see the evidence of a special distribution of stress related to the prescribed centres.

Petrographically the local groups of rocks show more variety than the regional series. Apart from some complications in the Mull district, the sequence, when complete, ranges from ultrabasic to acid in the plutonic phase, and the reverse in the phase of minor intrusions. The parent stock of all must have been the same basic magma as that which provided the plateau-basalts of the region and other rocks with evident alkaline affinities. None the less we find that, about the centres of acute disturbance in the interior of the tract, the local groups of rocks belong to distinctively calcic types: peridotite and allivalite, eucrite, gabbro and norite, augite- and hornblende-granite, and biotite-granite.[1] Towards the limits of the tract, where the locally developed stresses were much less intense, the alkaline facies reasserts itself in the plutonic rocks. This is shown in the north by the massive sheets of riebeckite-granite on Raasay, while in the south it is suggested by the Arran granites, rich in microperthite, and still more clearly by the paisanite of Ailsa Craig.

The same law is illustrated by the rocks of regional distribution themselves, where they come within the influence of the special centres of stress. The basaltic lavas of Central Skye seem to be decidedly of less alkaline composition than those in the northern part of the island. A like conclusion emerges when we compare the dolerite sills in the interior of the specified tract with those of

[1] An anomaly, from this point of view, is the occurrence of an alkali-syenite forming a reef opposite Carsaig, on the south side of Mull.

Raasay and the Shiant Isles in the north, or again with the analcime-dolerite (crinanite) sills of Southern Arran and the orthophyre with riebeckite and ægirine on Holy Isle. If we try to push the examination farther afield, where the only Tertiary rocks preserved are in the form of dykes, we find very few trustworthy data. A number of dykes in Argyllshire and elsewhere, belonging to very characteristic alkaline types, have sometimes been claimed as Tertiary, but I have assigned them, upon a balance of evidence, to a Permian age. When, however, we pass beyond the bounds of Scotland, southwards and westwards, we meet with a few scattered occurrences which have a special interest. The nepheline-basanite of Butterton, the phonolite of the Wolf Rock, and the peculiar ægirine-bearing type of Rockall are reasonably regarded as Tertiary. They are of much more strongly alkaline composition than the known rocks of this age in Northern Britain, and find their nearest relatives in the Cape Verd Isles and other island groups far to the south. If then we are to distinguish among the 'younger' igneous rocks of this part of the world a strongly alkaline North Atlantic region, connected with the collapse of considerable tracts in mid-ocean, and a less strongly alkaline Arctic region, including the Brito-Icelandic Province of Judd, we can point to one more important dividing line crossing the British area. It is in the nature of the case, however, that much of the evidence by which we might follow out this suggestion is buried beneath the waves.

Here I must bring my rough summary of igneous action in Britain to a close. Apart from personal shortcomings, it has suffered from necessary condensation and sometimes from the insular method of treatment imposed by considerations of time and space. I have tried to show that at different periods of its history our area has been differently mapped out into petrographical provinces, and this in a manner quite definitely related to the larger displacements of the earth's crust. The inference seems just that the distribution of crustal stress is a dominant factor in determining the petrographical facies of igneous rocks. One way in which this factor may operate has been suggested, and I venture to think that in any theoretical discussion of the question a place must be found for that intercrustal creep of alkaline magmas which I have specially emphasized. That it is

the only selective action determining the geographical distribution of different classes of igneous rocks is not claimed. In particular, any discussion of that question as a whole must try to assess the importance of isostasy, and the consequent tendency of the denser basic magmas to accumulate beneath the ocean-basins. This and some other elements of the larger problem may be eliminated in considering so small an area as the British Isles; which nevertheless can still produce, as I have shown, not a few unsolved questions to engage the attention of petrologists in the future.

February 28th, 1917.

Dr. ALFRED HARKER, F.R.S., President,
in the Chair.

Roger Howel, Bryncoch, Neath (Glamorgan); George Catterall Leach, Inspector of Mines, Sitarampur, E.I.R., Bengal (India); Ashley Gordon Lowndes, B.A., The Grange, King's School, Canterbury; and Ernest Neaverson, B.Sc., 16 Mandeville Road, Aylesbury, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communication was read:—

'Fourth Note on the Piltdown Gravel, with Evidence of a Second Skull of *Eoanthropus dawsoni*.' By Arthur Smith Woodward, LL.D., F.R.S., V.P.G.S. With an Appendix on the Form of the Frontal Pole of an Endocranial Cast of *Eoanthropus dawsoni*. By Prof. Grafton Elliot Smith, M.A., M.D., F.R.S.

Two fragments of skull and a tooth of *Eoanthropus dawsoni*, together with a supposed hammer-stone from the Piltdown gravel, were exhibited by Dr. A. Smith Woodward, F.R.S., V.P.G.S., in illustration of his paper.

Restored models of the Piltdown skull made by the British Museum and the American Museum of Natural History, and plaster casts of the original fragments on which these reconstructions were based were also exhibited by Dr. A. Smith Woodward.

A restored model of the Piltdown skull, made by the Royal College of Surgeons, was exhibited by Prof. Arthur Keith, F.R.S.

A plaster cast of a fossil human skull from Talgai (Queensland) was exhibited by Prof. G. Elliot Smith, M.A., M.D., F.R.S.

A mandibular ramus of a Chimpanzee, showing molar teeth worn flat, was exhibited by Mr. W. P. Pycraft, A.L.S.

March 14th, 1917.

Dr. A. SMITH WOODWARD, F.R.S., Vice-President,
in the Chair.

George Fairbairn, M.C., Assistant Commandant of Mines, R.E., 18 Welbeck Court, London, W.; and Major William Gregson, B.Sc., Blaina (Monmouthshire), were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communication was read :—

'The Carboniferous Limestone bordering the Leicestershire Coalfield.' By Leonard Miles Parsons, D.I.C., B.Sc., F.G.S.

Specimens and microscopic slides of dolomite, and fossils from the Carboniferous rocks of the Leicestershire Coalfield, were exhibited by L. M. Parsons, D.I.C., B.Sc., F.G.S., in illustration of his paper.

The following maps were also exhibited :—Geological Survey of Scotland : 1-inch Map, Sheets 36—Kilmartin, and 60—Rhum, 1917, presented by the Director of H.M. Geological Survey.

March 28th, 1917.

Dr. Alfred Harker, F.R.S., President,
in the Chair.

Guthrie Allsebrook, Moorland, Shinfield, near Reading; Thomas William Brown, B.Sc., A.M.S.E., 54 Brookvale Street, Belfast; and Scoresby Routledge, M.A., 9 Cadogan Mansions, Sloane Square, S.W. 1, were elected Fellows of the Society.

The List of Donations to the Library was read.

The President announced that the Council had awarded the Proceeds of the Daniel-Pidgeon Fund for the present year to Arthur Holmes, D.I.C., B.Sc., F.G.S., who proposes to conduct researches in connexion with the Geology of the Dartmoor Border, around Okehampton and Belstone.

The following communication was read :—

'The Carboniferous Limestone Series on the South-Eastern Margin of the South Wales Coalfield.' By Frank Dixey, M.Sc., F.G.S., and Thomas Franklin Sibly, D.Sc., F.G.S., University College of South Wales & Monmouthshire, Cardiff.

Lantern-slides, rock-specimens and microscope-slides of rocks from the Carboniferous Limestone Series on the South-Eastern Margin of the South Wales Coalfield were exhibited by F. Dixey, M.Sc., F.G.S., and T. Franklin Sibly, D.Sc., F.G.S., in illustration of their paper.

The following map was also exhibited :- Geological Survey of England & Wales—1-inch Map of Sheffield (Barnsley), temporary edition, 1917, presented by the Director of H.M. Geological Survey.

April 18th, 1917.

Dr. Alfred Harker, F.R.S., President,
in the Chair.

The List of Donations to the Library was read.

The following communication was read:—

'The Development and Morphology of the Ammonite Septum.' By Prof. Henry Hurd Swinnerton, D.Sc., F.G.S., and Arthur Elijah Trueman, M.Sc.

Specimens used in the investigation of the relationship between septal sections and stages in the sutural development of Ammonites, as also the instrument designed for taking measurements, were exhibited by Prof. H. H. Swinnerton, D.Sc., F.G.S., and A. E. Trueman, M.Sc., in illustration of their paper.

A series of Ammonites, some in section, and others ground to show the form of the edges of the septa, were exhibited by W. F. Gwinnell, B.Sc., F.G.S.

May 2nd, 1917.

Dr. Alfred Harker, F.R.S., President,
in the Chair.

The List of Donations to the Library was read.

The following communications were read:—

1. 'Supplementary Notes on *Aclisina* De Koninck, and *Aclisoides* Donald, with Descriptions of New Species.' By Jane Longstaff (*née* Donald), F.L.S. (Communicated by Dr. G. B. Longstaff, M.A., F.G.S.)

2. 'The Microscopic Material of the Bunter Pebble-Beds of Nottinghamshire and its Probable Source of Origin.' By Thomas Harris Burton, F.G.S.

Specimens of *Aclisina* and *Aclisoides* were exhibited by Mrs. Jane Longstaff, F.L.S., in illustration of her paper.

Lantern-slides and microscope-slides of pebbles and sands from the Bunter Pebble-Beds of Nottinghamshire were exhibited by T. H. Burton, F.G.S., in illustration of his paper.

There was also exhibited a geological map of Dublin, on the scale of 6 inches to the mile, 1917—presented by the Geological Survey of Ireland.

May 16th, 1917.

Dr. Alfred Harker, F.R.S., President, in the Chair.

[illegible] Joseph Fowler, M.A., [illegible] (Yorkshire), was elected a Fellow of the Society.

The list of Donations to the Library was read.

A lecture on "British Geological Maps as a Record of the Advance of Geology" was delivered by Thomas Sheppard, M.Sc., F.G.S. He observed that geological changes were in many cases indicated on old topographical maps; consequently, very old plans and charts were of use in connection with geological enquiries, although not strictly geological in character. Some examples of maps, dating from Elizabethan times, were exhibited, and these showed that in the Humber area great changes had taken place, [illegible] large tracts of land had been [illegible] and many towns and villages had disappeared; in others, large stretches of reclaimed land covered places where water once stood. As long ago as [illegible] attempts were [illegible] mineralogical differences in various parts of the country, and in 1683 Martin Lister read to the Royal Society a paper in which he ultimately suggested "A Scheme for the Mapping of Soils and Rocks," wherein he mentioned the various kinds of rocks that occurred in Yorkshire; but his scheme was not actually carried out until a century later. Strachey (1719) and Packe (1743) produced some remarkable geological sections and plans.

The first systematic series of maps illustrating the geological features of the counties was issued in the Reports of the old Board of Agriculture, and dated from 1793 to 1822. These Reports usually contained "soil-maps" of the counties described, upon which chalk, sandstone, limestone, peat, sand, gravel, etc., were shown by colours and shading. William Smith was certainly familiar with these "Agricultural Surveys," and doubtless they provided him with information that assisted him in the preparation of his great map of "The Geology of England and Wales," issued in 1815.

One of the earliest and most serious attempts to prepare geological maps was by [illegible], who read a paper in [illegible] "On [illegible] Maps" ([illegible]), published [illegible], and [illegible] an enormous number of complicated signs and symbols that he [illegible] general conception for practical purposes, although there were many good features in his schemes.

The first [illegible] geological map issued in the [illegible] was apparently that made by William Smith in [illegible], showing the geological structure of the Bath District. This had been shown by the lecturer to have been [illegible] on a plan originally issued in "The New Bath Guide" of [illegible]. The first geological map of

England and Wales was a small one, also by Smith, and it was presented to the Society by 'the Father of English Geology' when the first Wollaston Medal was awarded to him in 1831. The Lecturer discussed the history of the various maps and sections published by Smith, and described two hitherto unknown maps (of the counties of Durham and Northumberland) by the same author, in the Society's possession. He also exhibited one of the Scarborough district, found while he was cataloguing the Society's maps: all trace of this particular map had been lost for over eighty years. Smith's finest piece of work, his map of the Hackness district, dated 1832, apparently had not been seen by any worker since its publication, and the Lecturer explained how he had recently been able to trace two copies. One of them, which was exhibited, he presented to the Society.

In the Society's possession also is an extensive and valuable collection of the maps of Greenough, both published and in manuscript. Among an extraordinary series of coloured maps of England and Wales, and of the British Isles, issued during the middle of the 19th century, those of Arrowsmith, Murchison, Walker, Ramsay, Ravenstein, Knipe, Phillips, and Johnston are especially noteworthy.

The Society's collection includes geological maps of Scotland and Ireland, some of great value and historical interest. Of Scotland, the remarkable series by MacCulloch, published and in manuscript, shows that the collection is by far the finest as regards early maps dealing with the geology of the country. A manuscript map of Scotland by Necker is dated 1808 (earlier than Smith's large map of England and Wales), and is undoubtedly the oldest. Among the maps of Ireland there is the fine series by Griffith, which includes a few examples not known by Judd or other writers on the subject.

As examples of privately published maps, those by Sanders of the Bristol Coalfield, Jordan's London District, and Elias Hall's Lancashire area were described. The Lecturer concluded by referring to a Catalogue of geological maps (other than the Geological Survey Publications) which he had in course of preparation. This already contained details of approximately 3000 maps.

The PRESIDENT commented on the value of Mr. Sheppard's work, and on the important discoveries that he had made, and expressed the thanks of the Fellows present for his lecture.

Lantern-slides and examples of important early geological maps were exhibited in illustration of the lecture.

June 6th, 1917.

Dr. ALFRED HARKER, F.R.S., President,
in the Chair.

The List of Donations to the Library was read.

The following communications were read :—

1. 'On the Geology of the Old Radnor District, with special reference to an Algal Development in the Woolhope Limestone.' By Edmund Johnston Garwood, Sc.D., F.R.S., F.G.S., and Edith Goodyear, B.Sc.

2. 'Jurassic Chronology: I. Lias.' By S. S. Buckman, F.G.S.

Lantern-slides and specimens of rocks from the Old Radnor District were exhibited in illustration of the paper by Prof. E. J. Garwood, Sc.D., F.R.S., and Miss E. Goodyear, B.Sc.

Examples of Jurassic ammonites were exhibited by S. S. Buckman, F.G.S., in illustration of his paper.

June 20th, 1917.

Dr. Alfred Harker, F.R.S., President,
in the Chair.

John Cecil Mackmurdo Given, M.D., M.R.C.P., Lowood, Mossley Hill, Liverpool; William Watts Ratcliff, A.M.Inst.C.E., R.E., The Willows, West Drayton (Middlesex), Staff Officer to the Chief Engineer, XIIIth Army Corps; Ewart Watson Ravenshear, B.A., Captain, 7th Royal Berkshire Regiment; and Francis Whitworth Wright, J.P., B.A., M.I.M.E., Lieut. R.F.C., 141 Church Street, Chelsea, S.W. 3, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. 'The Pre-Cambrian and Associated Rocks of the District of Mozambique.' By Arthur Holmes, D.I.C., B.Sc., F.G.S.

2. 'The Inferior Oolite and Contiguous Deposits of the Crewkerne District (Somerset).' By Linsdall Richardson, F.R.S.E., F.G.S.

A manuscript map of the district of Mozambique, rock-specimens, and thin sections of rocks were exhibited by Arthur Holmes, D.I.C., B.Sc., F.G.S., in illustration of his paper.

The following were also exhibited: Geological Map of the Witwatersrand Goldfield, in three sheets (scale = 1 : 60.000; 1916)—presented by the Geological Survey of the Union of South Africa; and Geological Survey Map of Japan, Sheets Niagata & Shiriyazaki, 1916, and Takayama, 1917 (scale = 1 : 20,000)—presented by the Imperial Geological Survey of Japan.

THE

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FOR 1917.

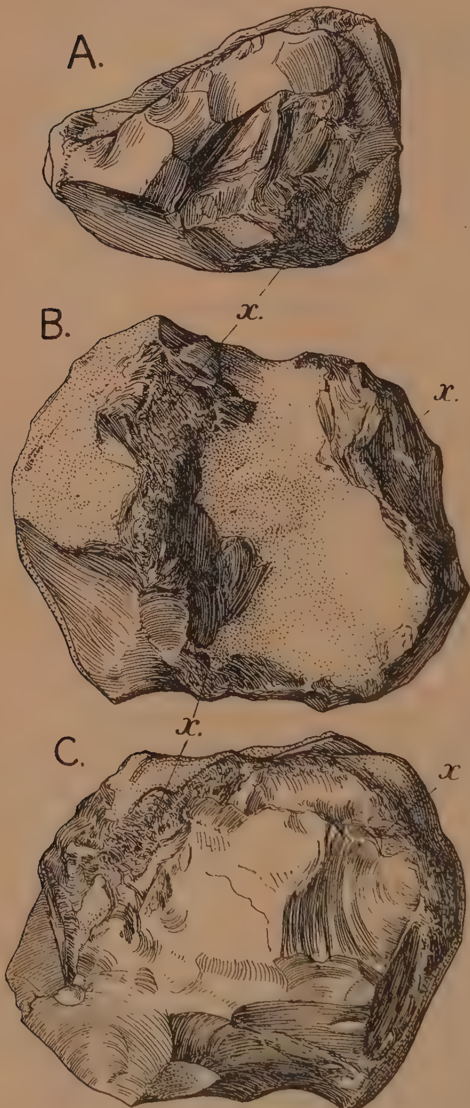
1. Fourth Note on the Piltdown Gravel, with Evidence of a Second Skull of *Eoanthropus dawsoni*. By Arthur Smith Woodward, LL.D., F.R.S., V.P.G.S. With an Appendix by Prof. Grafton Elliot Smith, M.A., M.D., F.R.S. (Read February 28th, 1917.)

[Plate I.]

The Piltdown gravel has already been well described by the late Mr. Charles Dawson,[1] who pointed out its variable character and concluded that its two lower layers at least could not be very different in age.[2] Further extensive excavations last summer round the margin of the area previously explored, tended to confirm this impression, and to show that the whole deposit is a shingle-bank which may have accumulated within a comparatively short space of time. The lenticular patches of the dark-brown ferruginous gravel proved to be even more variable than before, and they were seen to pass both into the sandy clay below and into the less clayey deposit above. Large flints and waterworn pieces of Wealden sandstone were still observed scattered irregularly through the finer material. The characteristic 'subangular flints' were also found at intervals in the basal sandy clay. More interesting, however, was the discovery in this layer of numerous large elongated flints and pieces of Wealden sandstone, with their long axis more or less nearly vertical. The evidence of flood-action thus became complete.

[1] Q. J. G. S. vol. lxx (1914) p. 82
[2] *Ibid.* vol. lxxi (1915) p. 147.

Fig. 1.—*Supposed hammer-stone of flint from the Piltdown Gravel; half of the natural size.*



[A=side view; B=face showing the original crust of the flint; C=extensively-flaked face: x= battered portions.]

Although so much material was carefully examined, neither bones nor teeth were met with. The only noteworthy find was a battered nodule of black flint, which occurred in a rather sandy patch of the dark-brown gravel resting immediately on the basal layer. This specimen, which is conspicuously different from the other flints and very little stained, may have been used by man as a hammer-stone (text-fig. 1). It measures nearly 13 centimetres in length by 9·5 cm. in width, and about 7·5 cm. in maximum thickness. The largest face (C), which is almost flat, has been produced by coarse flaking, and bears marks of much battering round the edge, especially at one angle (x). The opposite large face (B) is covered for the greater part by the original crust of the flint-nodule, but is strongly battered along the two cross-ridges (x) and one connecting edge, from which lateral flakes have been struck. Where not thus flaked the periphery of the flint is also covered with the original crust. Like the later undoubted hammer-stones, therefore, this flint has been used mainly on two opposite faces; but it appears to owe its present form merely to use,

not to any original intentional shaping. All the edges are remarkably sharp, and the black facets bear scarcely any patina.

The wide distribution of the Piltdown gravel, as determined by its characteristic brown flints, was shown by Mr. Dawson in his map of 1912.[1] It could easily be traced in the ploughed fields of the district; but, notwithstanding the most careful and persistent search, it yielded no fossils, except at the original locality, until the winter of 1914–15. One large field, about 2 miles from the Piltdown pit, had especially attracted Mr. Dawson's attention, and he and I examined it several times without success during the spring and autumn of 1914. When, however, in the course of farming, the stones had been raked off the ground and brought together into heaps, Mr. Dawson was able to search the material more satisfactorily; and early in 1915 he was so fortunate as to find here two well-fossilized pieces of human skull and a molar tooth, which he immediately recognized as belonging to at least one more individual of *Eoanthropus dawsoni*. Shortly afterwards, in the same gravel, a friend met with part of the lower molar of an indeterminable species of rhinoceros, as highly mineralized as the specimens previously found at Piltdown itself.

The most important fragment of human skull is part of the supraorbital region of a right frontal bone adjacent to the middle line (Pl. I, figs. 1 *a*–1 *d*). It is in exactly the same mineralized condition as the original skull of *Eoanthropus*, and deeply stained with iron-oxide. It is also similarly thickened, exhibiting the characteristic very fine diploe with comparatively thin outer and inner tables of dense bone. It provides a portion that was absent in the first specimen, its upper end approaching within a few millimetres the level of the anterior broken edge of the left frontal in the latter, while its lower portion now leaves only about 2 cm. of the supra-orbital border unknown. Its gently upward and backward curvature (figs. 1 *c* & 1 *d*) is that already assumed in restorations, and its outer face is marked only by a small and low supraciliary ridge (*s.*), which is well above the orbital border, fades away medially at the beginning of the glabella, and only extends laterally just beyond the supraorbital notch (*n.*). On the inner face of the bone (fig. 1 *b*) the median border bears an unusually stout sagittal crest (*c.*), which is slightly marked by a groove for the longitudinal sinus. The impressions of the convolutions of the frontal lobe of the brain are feeble, but show some features of interest, as described by Prof. Elliot Smith in the Appendix (p. 7). The orbital plate, as might be expected, is broken away, and the rather tumid glabellar region is imperfect below, exposing small air-sinuses, which do not appear to extend along the supraorbital border beyond the supraorbital notch. This notch (figs. 1 *a* & 1 *b*, *n.*) is especially conspicuous (perhaps enlarged by abrasion in the fossil), and the supraorbital border to the right of it forms a comparatively sharp edge (figs. 1 *a*, 1 *b*, & 1 *d*). The median plane of fracture (fig. 1 *c*) follows closely the

[1] Q. J. G. S. vol. lxix (1913) p. 118.

line of the interfrontal suture, which, however, judging from the appearance of the broken surface, cannot have been persistent. It shows a complete septum (*a.*) between the air-sinuses of the right and left sides, and indicates the total thickness of the bone at the frontal crest.

The following are some measurements of thickness of the new fossil, in millimetres :—

Supero-lateral angle	10
Thinnest part of lateral edge	8
Sharp supraorbital border (fig. 1 *d*)	12
Upper end of sagittal crest	13
Lower end of sagittal crest	19

With these may be compared the following measurements of thickness of the original specimen of *Eoanthropus* :

Left frontal at the nearest point of approach to the part represented by the new fossil	11
Thinnest part of frontal above the left orbit	9

The second fragment of human skull is the middle part of an occipital bone, which is also well fossilized, but seems to have been weathered since it was derived from the gravel (Pl. I, figs. 2 *a*–2 *c*). Though still stout, it is thinner than the corresponding bone of *Eoanthropus* from Piltdown, and differs from the latter in at least one important respect. The outer face of the fossil (fig. 2 *a*) extends upwards just beyond the superior curved line (*s.c.l.*) which passes along a gentle transverse prominence; while the lower edge of the fragment is a little below the inferior curved line (*i.c.l.*). The inner face (fig. 2 *b*) shows the internal occipital crest (*i.o.c.*), with its protuberance, displaced somewhat to the right of the median line, the fossa for the left cerebral hemisphere (*cer.*) being relatively wide. The broad transverse grooves for the lateral sinus (*l.si.*), however, are at the same level on the right and left sides, and the upwardly turned groove at the torcular Herophili (*t.*) of the longitudinal sinus is large and conspicuous on the right. The fossæ for the cerebellum (*cb.*) indicate very little asymmetry. The brain must thus have been much more nearly symmetrical than that of the original specimen of *Eoanthropus*—a difference that is to be regarded as merely an individual variation. When, however, a vertical section of the bone is made along the external occipital crest (fig. 2 *a*, *e.o.c.*) which marks the median plane (fig. 2 *c*), an essential difference is observable between this and the previously-described specimen. The superior curved line of the outer face and (by inference) the inion, or external occipital protuberance, are distinctly above the level of the upper edge of the lateral sinus which denotes the limit of the tentorium covering the cerebellum; whereas, in the first specimen, the same external

and internal features are opposite, as in modern man. It is therefore clear that, in the skull represented by this new fossil, the muscles of the neck must have extended farther up the occiput than is usually the case. Such an upward extension of the neck-muscles is already known in Neanderthal man, where it is supposed to be correlated with the support of a heavy face; and it may be that in still earlier man the condition was variable, perhaps even different in the male and in the female. If this were so, there would be no reason to hesitate in referring the fragment now described to *Eoanthropus dawsoni*.

The following are some measurements of thickness of the new occipital bone, compared with that of *Eoanthropus* previously described:—

	New fossil.	*Eoanthropus.*
Greatest thickness	17 mm.	20 mm.
Thickness at internal protuberance ...	16 mm.	20 mm.
Thinnest part of cerebellar wall	4 mm.	4 mm.

The tooth, discovered by Mr. Dawson in the same locality as the two pieces of bone, is a left first lower molar (Pl. I, figs. 4 *a*–4 *e*) agreeing very closely with that of the original specimen of *Eoanthropus dawsoni*, but more obliquely worn by mastication. It is equally well fossilized, and stained brown with oxide of iron in the usual manner. The difference in the mode of wear can be seen in its anterior end-view (4 *e*) when this is compared with that of the original specimen (fig. 5). The tooth, as before, is elongated antero-posteriorly, and its grinding surface (fig. 4 *a*) lacks any well-defined cruciform fissure, its central area being an irregular, nearly smooth depression. Of its two inner cusps, the anterior is the larger, and must have been more elevated than the posterior cusp (its worn apex exposing a small triangular area of dentine, while the latter is still covered with enamel). Both the outer cusps are worn down to the dentine, the anterior exposing a slightly larger area than the posterior cusp. The small fifth cusp behind is, as usual, nearest the outer border, from which it is visible in side view (fig. 4 *b*). It is also worn down so as to expose a very small area of dentine. Between this, the postero-internal cusp, and the posterior border of the tooth, the crown (fig. 4 *a*) is slightly marked by a small transversely-extended depression. In outer view (fig. 4 *b*) and inner view (fig. 4 *c*), the depth of the crown is well seen, and the two cusps are clearly separated by a fissure. At both ends of the tooth (4 *d*, 4 *e*), a pressure-scar is distinguishable. The two roots, of which only the upper portions are preserved, are separate nearly as far as the neck of the tooth, which is but slightly constricted.

If the new tooth be compared with the corresponding molars of a Melanesian (figs. 6 *a*–6 *e*), a Tasmanian (figs. 7 *a*–7 *d*), and a Chimpanzee (figs. 8 *a*–8 *e*), of approximately the same size, it will readily be recognized as essentially human. In the considerable

depth of the crown and its gradual passage into the root, it agrees with the human tooth and differs from that of the Chimpanzee, in which the crown is very brachyodont and overhangs the root. As a human molar it is unusual in the feebleness of its cruciform fissure, and in the presence of the slight depression on the crown behind the postero-internal and fifth cusps; but both these features are approached in the Melanesian tooth selected for comparison (Pl. I, fig. 6 *a*). In the antero-posterior elongation of the crown and in the characters just mentioned, it obviously resembles the corresponding tooth of the Chimpanzee (fig. 8 *a*); but the cusps in the latter are so brachyodont that much larger areas of dentine are exposed when they are worn down to the level reached in the fossil. These comparisons are made because it has been stated that the molar teeth in the Piltdown mandible are those of a Chimpanzee[1]: reference to the teeth of other known Apes is not necessary.

The following are the extreme measurements (in millimetres) of the teeth taken between the convexities of the sides:—

	Melanesian.	*Tasmanian.*	*New Tooth.*	*Chimpanzee.*
Length...............	13	13	13	12
Width	11·5	11·5	11	10·5

The following are similar measurements of the two lower molars in the original specimen of *Eoanthropus dawsoni*:—

	M_1.	M_2.
Length	12·5	13
Width	11	11·5

From the new facts now described it seems reasonable to conclude that *Eoanthropus dawsoni* will eventually prove to be as definite and distinct a form of early Man as was at first supposed; for the occurrence of the same type of frontal bone with the same type of lower molar in two separate localities adds to the probability that they belonged to one and the same species.

Again I have to thank the Lord of the Manor, Mr. G. M. Maryon Wilson, and the tenant of Barkham, Mr. Robert Kenward, for facilities in continuing the exploration of the Piltdown gravel-pit. I am also indebted to Mr. C. G. Turner, of Uckfield, for much kind service. Finally, I desire to thank my colleague, Mr. W. P. Pycraft, A.L.S., for his valuable help in making comparisons with the osteological collection under his charge.

[1] G. S. Miller, 'The Jaw of the Piltdown Man' Smithson. Miscell. Collect. vol. lxv, No. 12 (1915). Endorsed by W. K. Gregory, 'Studies on the Evolution of the Primates' Bull. Amer. Mus. Nat. Hist. vol. xxxv (1916) pp. 313 20. Replied to by W. P. Pycraft, 'The Jaw of the Piltdown Man' Science Progress, No. 43 (1917) pp. 389–409.

EXPLANATION OF PLATE I.

[All the figures are of the natural size.]

Fig. 1. *Eoanthropus dawsoni* A. S. Woodward. Inner supraorbital portion of right frontal: outer view (1 *a*); inner view (1 *b*); section along sagittal crest (1 *c*); and section at outer edge (1 *d*). *a.*=air-sinus; *c.*=frontal crest; *n.*=supraorbital notch; *s.*=supraciliary ridge.

2. *Eoanthropus dawsoni.* Middle portion of occipital: outer view (*a*); inner view (*b*); and vertical median section along external occipital crest (*c*). *cb.*=cerebellar fossa; *cer.*=cerebral fossa; *e.o.c.*=external occipital crest; *i.o.c.*=internal occipital crest; *i.c.l.*=inferior curved line; *l.si.*=groove for lateral sinus; *s.c.l.*=superior curved line; *t.*=groove above torcular Herophili.

3. *Eoanthropus dawsoni.* Vertical median section of the occipital bone of the type-specimen along the external occipital crest. Lettering as in fig. 2, with addition of *i.*=inion.

4. *Eoanthropus dawsoni.* Left first lower molar: crown (*a*); outer (*b*), inner (*c*), posterior (*d*), and anterior (*e*) views.

5. *Eoanthropus dawsoni.* Right first lower molar of the type-specimen, anterior view.

6. Left first lower molar of Melanesian: crown (*a*); outer (*b*), inner (*c*), posterior (*d*), and anterior (*e*) views.

7. Left first lower molar of Tasmanian: crown (*a*); outer (*b*), inner (*c*), and posterior (*d*) views.

8. Left first lower molar of large Chimpanzee: crown (*a*); outer (*b*), inner (*c*), posterior (*d*), and anterior (*e*) views.

APPENDIX.

On the Form of the Frontal Pole of an Endocranial Cast of *Eoanthropus dawsoni*.

By Prof. G. ELLIOT SMITH, M.A., M.D., F.R.S.

Although the fragment of the right side of the frontal bone reveals the form of only a small area (little more than 5 cm. long × 3 cm. broad) of the endocranial surface, which is devoid of obtrusive features, it is of interest and importance because it sheds some light upon a part of the endocranial cast of which nothing was known before. Moreover, it is a part of the cast, the frontal pole, the form of which is of peculiar significance in the study of the features of early Man.

In a communication dealing with the endocranial cast of the Boskop skull, which I presented to the Manchester Literary & Philosophical Society last month,[1] I called attention to the small size and lack of roominess of the prefrontal region of the cranial cavity in Neanderthal man, and made special use of the form and relative size of the prefrontal area of the Boskop cast to establish

[1] This will be published in the Transactions of the Royal Society of South Africa.

the fact that the skull from which it was obtained conformed to the modern type (by some authorities regarded as the species *Homo sapiens*, as distinct from *H. neanderthalensis*).

The small fragment of endocranial cast now under consideration presents at its medial border about 4·5 centimetres of the broad deep median furrow, corresponding to the endocranial sagittal crest of the frontal bone; and below, part of the orbital margin, although not sufficient to display the form and extent of the orbital rostrum. There are no distinct indications of the situations of any of the cerebral sulci, although there is a definite flattening of the surface parallel to, and about 1 centimetre above, the orbital margin. Passing upwards from the middle of this flattening is an even more definite depression (fig. 2, *b*) proceeding sagittally at a distance of about 2 centimetres from the median plane. The surface between this depression and the median groove is raised up into a prominent hillock (*a a*), the exact analogy for which I have been unable to find in any human brain or cranial cast. It presents a much closer analogy to the condition found in the casts of skulls of the Neanderthal series (more especially the Gibraltar, Neanderthal, and La Quina casts) than in those of any more recent varieties of man. But it suggests also the paramedian ridge formed by the anterior part of the superior frontal convolution in the anthropoid apes, the prominence of which is due in part to the falling away of the ill-developed lateral part of the prefrontal area.

Fig. 2.—*The frontal pole of an endocranial cast of* Eoanthropus *viewed from the front.*

[*a* = paramedian eminence; *b* = depressed area at the lateral border of the eminence; *c* = part of the fronto-orbital margin.]

If these tentative suggestions are justified, this small fragment affords further corroboration of the opinion that I expressed with reference to the endocranial cast of the Piltdown skull: namely, that it presents features which are more distinctly primitive and ape-like than those of any other member of the human family at present available for examination.

G. M. Woodward, del.

Bemrose, Collo., Derby.

EOANTHROPUS DAWSONI.

Discussion.

Mr. W. P. Pycraft exhibited a specimen of the right half of a mandible of a chimpanzee, sent to him for examination by Mr. Gerritt T. Miller, of the Smithsonian Institution, Washington. Mr. Miller, in his Memoir on the Piltdown jaw, laid no little stress on the importance of this specimen, from the fact that the molars are worn so as to present flattened crowns similar to those of the Piltdown jaw. Hence, this specimen formed a link in his chain of evidence that the Piltdown jaw was unquestionably that of a chimpanzee.

It is clearly the jaw of an adult of one of the small races of chimpanzee, and apparently of a female. But, as a witness for Mr. Miller, it must be held to have failed; because, although the molars are worn flat, this is due, not to normal wear, but to some interference in the normal 'bite' of the jaw caused by the abnormal position of PM_1, which projects above the level of the worn surface of the molars as much as 5 mm. That this is not due to *post-mortem* displacement is clear, since the posterior border of the crown, where it impinges upon the anterior border of PM_2, shows no sign of facetting as a consequence of the mutual pressure of the two teeth. Nor does the crown show any sign of wear. Unfortunately about half of this is missing, the tooth having split longitudinally.

The second premolar shows but very slight signs of wear, and is conspicuously flat-topped—a feature peculiar to the tooth rather than due to wear.

The first molar is, as Mr. Miller described it, worn to a flat-topped surface, but the wear has been from in front backwards, so that the crown presents a decided backward slope when seen in profile.

The surface of M_2, though worn flat, is not in the same plane as that of M_1. This much can easily be demonstrated if a straight-edge be placed over the two teeth; a large wedge-shaped gap will then be found between the straight-edge and M_1, the apex of the wedge being pointed forward. The worn surface of this tooth (M_2) is not absolutely flat, but presents a shallow depression running from the entoconid obliquely forwards to the protoconid.

The incisors have been worn down to about half their original length.

In no other chimpanzee that the speaker had examined had he ever found anything in the matter of wear comparable with the molars of Mr. Miller's specimen. These are quite abnormal in this regard, and therefore of no value as evidence that the Piltdown teeth might, even in the wear of their crowns, agree with teeth of chimpanzees. Normally, one might affirm that the molars of these animals never wear flat; but the outer cusps disappear before the inner cusps are perceptibly reduced by wear.

Prof. A. Keith said that these further Piltdown 'finds' established beyond any doubt that *Eoanthropus* was a very clearly-differentiated type of being—in his opinion a truly human type. He agreed with Dr. Smith Woodward and Mr. Pycraft that the lower molar now found and the original mandible and teeth must be ascribed to *Eoanthropus*, and constituted the characteristic features of the type. He did not think that the relationship of the external occipital protuberance to the position of the lateral venous sinuses had any great value in the differentiation of human species. Among modern English skulls it was not uncommon to find the external occipital protuberance above the level of the lateral sinuses, as in the newly-found fragment. The position of the protuberance changed with age, and it ascended on the occiput as the neck expanded; it was low in position in women and children, and high in men with thick necks. The high position of the protuberance in the specimen found either indicated that it belonged to an older individual than the type-specimen, or pointed to a difference of sex. The frontal fragment was a particularly valuable addition, because it cleared up any doubt as to the contour of the forehead over the root of the nose. The supraciliary parts of the supraorbital bar were but slightly prominent, there being a wide shallow depression separating the right and left supraciliary eminences. The depth and thickness of the internal frontal crest were altogether remarkable.

Sir Ray Lankester said that all must appreciate the clear and interesting statement made by Dr. Smith Woodward. He congratulated the Author on the gradual addition, by his patient work and that of the late Mr. Charles Dawson, of new bits to our knowledge of the Piltdown man. He pointed out that it was a possibility—although highly improbable—that the piece of the frontal bone and also the molar tooth now described belonged to the same individual as that represented by the imperfect skull and lower jaw already known. But this was not true of the fragment of the occipital bone, since the region corresponding to this fragment was present in the imperfect skull now in the Natural History Museum. The present 'find' therefore makes it impossible to regard the Piltdown man as an isolated abnormal individual. The fragments hitherto found must be referred to two, and possibly to three or even four individuals.

Mr. W. Dale observed, with regard to the flint that was said to have been used as a hammer-stone, that it had probably sunk down from a higher level and was of newer date. At a previous meeting on the same subject, palæolithic implements had been shown which were of the deep-ochreous colour of the bones. This 'hammer-stone' was scarcely patinated at all.

Dr. A. Smith Woodward thanked the Fellows present for their reception of his paper, and mentioned that the new specimens of *Eoanthropus* exhibited had been presented by Dr. F. DuCane Godman to the British Museum.

2. *On a* Spilitic Facies *of* Lower Carboniferous Lava-Flows *in* Derbyshire.

By Henry Crunden Sargent, F.G.S.

(Read February 7th, 1917.)

Contents.

I. Introduction.

The igneous rocks of Derbyshire, locally called 'toadstones,' form a well-known basic series comprising lava-flows, sills, a few thin dykes, and also, in many localities, pyroclastic material varying from coarse agglomerate to fine-grained tuff. All these rocks occur entirely in beds of Lower Carboniferous age. The lava-flows and ashes were contemporaneous with the Carboniferous Limestone, with the exception of a few small occurrences in the south-west of the county which are in the Limestone Shales overlying the limestone. That they were submarine is evident from their intercalation at various horizons in marine deposits. There would appear to have been a large number of vents scattered over a sea-floor that was undergoing slow and prolonged subsidence.

Dr. Bemrose [1] has classified the lavas and sills under three heads, namely: (1) olivine-dolerites, (2) ophitic olivine-dolerites, and (3) olivine-basalts. These distinctions rest on internal structure alone, and not on mode of occurrence, intrusive or extrusive.

In the course of a visit of the Geologists' Association to Derbyshire in the summer of 1914, specimens of lava were collected in Tideswell Dale which appeared, on examination under the microscope, to vary widely in character from the dolerites and basalts of the county hitherto described. Dr. Harker, to whom a thin section was submitted, pointed out that it possessed decided affinities with the spilites of Devon and Cornwall, and also, to some extent, with the mugearites of East Lothian. It seemed desirable, therefore, to make a further examination of the rocks of the district, in order to ascertain to how great an extent these features occurred elsewhere, and the object of this paper is to record the result.

I desire to express my great indebtedness to Mr. A. T. Metcalfe, F.G.S., who was the first to note the special features of the Tideswell-Dale rock and urged me to undertake the investigation.

[1] Q. J. G. S. vol. l (1894) p. 624.

II. The Lavas

The features of the Tideswell-Dale rock that directed attention to the subject were (*a*) the abundance of oligoclase among the felspathic constituents: (*b*) the occurrence of albite in the vesicles; and (*c*) the subordinate part played by augite as compared with olivine. Many specimens from other areas of the county have now been examined under the microscope; and, although from numerous exposures, Dr. Bemrose's petrographical description[1] is fully borne out, there are many from various localities which possess features similar to those of the Tideswell-Dale rock. Such localities as have been hitherto noted by me are set forth in the accompanying list, and it will be seen that all the main flows of the county, as mapped by Dr. Bemrose, are represented, as well as several of those which he describes as 'uncorrelated.'[2] With the exception of Kniveton, all the localities are in the Carboniferous Limestone.

Locality.		*Horizon.*
1. Ball Eye, Via Gellia, near Cromford.	Matlock Area	Upper Lava.
2. Salter's Lane, Matlock		Do. do.
3. Masson, Matlock		Do. do.
4. Dobb Lane, Bonsall		Lower Lava.
5. Ember Lane, Bonsall		Do. do.
6. Aldwark Grange, near Grange Mill.		Uncorrelated.
7. Sacheveral Barn, near Grange Mill.		Do.
8. Knot Low, Millers Dale	Millers Dale Area.	Upper Lava.
9. Tideswell Dale		Lower Lava.
10. Tideswell Dale		Uncorrelated.
11. New Bridge, near Ashford		Do.
12. Conksbury Bridge, Lathkill Dale.	Upper Lava of Lathkill Dale.	
13. Bradford Dale, Youlgrave	Bakewell Area	Uncorrelated.
14. Lumford Mill, near Bakewell		Do.
15. Crich Cliff	Doubtful.	
16. Kniveton	Tissington Area	Limestone Shales.

In both macroscopic and microscopic characters the Derbyshire lavas show a rather wide range. Their colour varies from different shades of grey, green, or blue, to black. Their texture may be fine-grained or coarsely crystalline, with gradations from one extreme to the other.

The rocks with which this paper is concerned belong to the leucocratic end of the series. They are nearly always vesicular and always intensely altered. Both olivine and augite appear to have been invariably present in the original rock, the former sometimes preponderating over the latter, as already noted in the Tideswell-Dale specimen; but, under the microscope, both minerals are always seen to be completely destroyed. The evidence of their former presence consists in a more or less complete recrystallization, pseudomorphous or otherwise, of secondary products such as calcite, quartz, and minerals of a chloritic or

[1] Q. J. G. S. vol. l (1894) pp. 611–25.
[2] *Ibid.* vol. lxiii (1907) pp. 247 & 251.

serpentinous character, often with radial and spherulitic structures. Iron-ores, both magnetite and ilmenite, are generally abundant.

But, amid the general wreck of the other constituents, the felspars stand out conspicuously as much less altered. They retain their crystal-form, though their edges are always ragged and corroded. Their interiors, when original, are clouded with alteration-products; but not seldom they are quite fresh and water-clear, apparently as the result of a replacement of the original felspar-substance by secondary material.

In all the localities named above the felspathic element predominates, and not infrequently forms the bulk of the rock. It occurs as phenocrysts, laths, or microlites, and sometimes in allotriomorphic interstitial fragments. In general, porphyritic structure is not very noticeable, and it is often absent. In a few localities large felspar-phenocrysts abound [1; 13].[1] In many of the thin sections the felspar-content is seen to consist wholly of laths of fairly uniform size, and in a few it is almost entirely microlitic [9; 11; 16]. The species, too, show a rather wide range. Oligoclase appears to be always present among the laths and microlites, and sometimes it is the dominant felspar. Its identity is known by the extinction-angles which, in sections normal to the albite-lamellæ, range from zero to 6°; and by the refractive index which, when it can be compared with that of the balsam, is seen to be about the same, or a very little higher. More often than not, comparison with the index of the balsam is obscured by alteration-products in the felspar. Subordinately, a more basic plagioclase occurs among the laths, and this may generally be referred to andesine or to an acid labradorite. When phenocrysts of original composition are present, they are often more basic than the felspar of the ground-mass, and belong to the andesine-labradorite series.

In addition to plagioclase there is undoubtedly a considerable proportion of potash-felspar, which is assumed to be orthoclase and is often of a secondary character, in these rocks. Sometimes, when a large amount of replacement of the original laths has taken place, it becomes the dominant species [2; 3]. This view is borne out by both the microscopic examination and the analyses. Carlsbad twins extinguishing simultaneously when parallel with the cross-wires occur in both phenocrysts and laths, and untwinned crystals extinguishing straight are seen in many of the sections. Very low refractive indices, lower than that of the balsam, may be seen in many of these individuals. Shapeless fragments of felspar-substance, probably orthoclase, also occur interstitially in some of the sections.

Zoned felspar-crystals are not uncommon, a thin outer zone less basic than the interior and with straight extinction being often seen on the laths.

[1] Numbers in square brackets refer to the localities enumerated in the list on p. 12.

Dr. Bemrose has noted that, in specimens from three outcrops examined by him,

'the ground-mass sometimes consists of a small felt of felspar-laths often giving parallel extinction.'[1]

It is interesting to contrast these rocks with those at the other end of the series, the darker rocks which are of normal basaltic or doleritic type. It is unnecessary to describe these in detail, since Dr. Bemrose has already done so[2]; but a point of importance bearing, as I conceive, on the evolution of the whole series, is their general freshness as compared with the rocks above described. They are sometimes beautifully fresh and well preserved, the principal sign of alteration being slight serpentinization of the olivine.

A more detailed description of a few of the more noteworthy rocks with spilitic affinities may now be given. This will be mainly confined to the felspathic content, since the general description of the other constituents given above holds good for all.

In the rock from Ball Eye, Via Gellia [1], the felspar occurs in two generations: large lath-shaped phenocrysts and a ground-mass of microlites. Many of the phenocrysts are twinned on the albite law, and show extinction-angles which point to andesine-labradorite. Carlsbad twins with simultaneous or unsymmetrical extinctions, and untwinned crystals extinguishing straight, also occur in subordinate quantity. The microlites of the ground-mass appear to be dominantly oligoclase. Very little, if any, replacement by secondary felspar has taken place here.

The Salter's Lane and Masson rocks [2 & 3] are both outcrops of the Upper Lava of the Matlock area. The former was collected *in situ*; the latter was obtained from the waste-heaps of the Seven Rakes Mine, now closed. The rock is sub-porphyritic, the felspar-content consisting of a few small phenocrysts and a mass of laths of fairly uniform size. The phenocrysts are altered throughout to a water-clear felspar-substance associated with patches of calcite. The laths are sometimes similarly altered; but often the secondary felspar is seen on the margins only, the interior forming a spongy core of chlorite and calcite. Vestiges of albite-twinning occur in some of the laths, and the secondary calcite suggests that labradorite was originally present. The secondary felspar has a lower refractive index than the balsam, and in view of the analyses (Nos. VI & VII, p. 22) it must be assumed to be orthoclase.

The lava-flow on Knot Low, Millers Dale [8], is about 120 feet thick. At the summit the rock below the zone of atmospheric weathering is a fresh basalt; at the base it is of spilitic character, and is altered throughout. It is non-porphyritic; the felspars are all lath-shaped, frequently untwinned, and sometimes twinned on

[1] Q. J. G. S. vol. l (1894) p. 624.
[2] *Ibid.* pp. 611–25.

the Carlsbad law. Extinctions are straight, or with a very low angle.

The Tideswell-Dale flow [9] is well seen in a small disused quarry directly south of the North Fault, as mapped by Dr. Bemrose,[1] where the specimens mentioned on p. 11 were collected. Both vesicular and non-vesicular rocks are well exposed. The former has already been briefly described: it consists mainly of a mass of felspar-laths and microlites with flow-structure. They appear to be chiefly oligoclase, but subordinate andesine also occurs. Felspar-phenocrysts are absent.

In the non-vesicular rock, which overlies the vesicular portion, large felspar-phenocrysts are very abundant. The transition from non-porphyritic to porphyritic rock is absolutely abrupt, and a clear line of demarcation, marked by the greater alteration of the underlying vesicular rock, is well seen. There can hardly be a doubt that the porphyritic rock is a distinct flow from the underlying spilitic bed. Its phenocrysts are frequently very long and lath-shaped. Untwinned individuals occur among them, and these have straight extinction; but most of the crystals have extinction-angles which show that a felspar predominates which is more basic than that in the vesicular portion of the exposure. The dominant species appears to be andesine, but subordinate oligoclase also occurs, and probably some orthoclase as well. Augite is present in fairly fresh condition, moulded on the felspars, and it is clear that this bed does not come within the range of the spilitic type of these lavas. Nevertheless, here too, replacement of the original felspar by alkali-felspar appears to have commenced along cracks and fissures in the phenocrysts.

The lava of Crich Cliff [15] can now be collected only on the waste-heaps of abandoned mines. Examples of both types of rock may be found. The comparative freshness of the basalts is very striking, when compared with specimens having spilitic affinities. In the former granular augite is abundant, and remains of unaltered olivine may be seen. A few felspar-phenocrysts occur, but the bulk of the felspar-content is in the form of laths. Extinction-angles indicate labradorite as the dominant species; but untwinned water-clear crystals, with straight extinction and apparently of secondary origin, occur in subordinate quantity. In specimens with spilitic affinities from the same waste-heaps the dominant original felspar is sometimes oligoclase, sometimes andesine-labradorite; but replacement on a considerable scale has taken place, and the other constituents are always destroyed. Here, too, untwinned laths and Carlsbad twins with straight extinction occur.

The lava of Worm Wood, near Bakewell, is a good example of a rock intermediate between those of spilitic type and the true

[1] Q. J. G. S. vol. lv (1899) map, pl. xix.

basalts. The phenocrysts here are entirely replaced by alkali-felspar enclosing small patches of secondary calcite, which probably indicate labradorite as the original felspar. They are twinned on the albite law, and have extinction-angles indicating andesine or an acid labradorite. Their refractive index is higher than that of the balsam. Messrs. E. B. Bailey & G. W. Grabham's observation[1] that, in a porphyritic basalt, the phenocrysts are always attacked before the less basic felspars forming the ground-mass, is thus confirmed here, as well as elsewhere, in the Derbyshire rocks.

The study of the vesicles affords matter of much interest. Frequently they are lined with a very thin layer of a fibrous green chloritic substance, the fibres standing out from the wall of the cavity. The birefringence of this mineral is higher than that of chlorites in general. The following minerals occur in the interior of the vesicles, generally two or more together: quartz, chalcedony, calcite, dolomite, albite, and chlorite. The sequence observed in the deposition of these minerals varies in different vesicles. Granular quartz frequently occurs in small grains or narrow strips associated with the outermost chloritic lining, or itself forming the actual lining of the cavity. When quartz and calcite are associated, the quartz has generally separated out before calcite. Rarely, the reverse is the case, and dogtooth crystals of an outer zone of calcite are seen penetrating an inner zone of quartz. Dolomite is often associated with calcite. Helminth is the most abundant form of chlorite, and there is sometimes present a yellowish-brown fibrous mineral, pleochroic and with low birefringence, which may be near delessite. Sometimes these chloritic minerals fill the entire vesicle, or, in a composite amygdale, they may be formed at any stage relatively to the other minerals in the vesicle. In the vesicles described by Messrs. Bailey & Grabham[2] a regular sequence of deposition occurs, namely: (*a*) albite, (*b*) chlorite, and (*c*) calcite.

It is clear from the foregoing description that there is a facies of lava-flows in Derbyshire presenting characters widely different from those of the true basalts. That they have structural trachytic affinities is obvious from the predominance of alkali-felspar consisting of a mass of laths and microlites, sometimes exhibiting fluidal arrangement and often forming the bulk of the rock. On the other hand, they are essentially more basic than the trachytes, as is shown by their low silica-content, their abundant iron-ores, and the presence of olivine.

There is no need to emphasize the points of resemblance and difference between these rocks and those of the spilitic and mugearitic groups. Like the spilites, the Derbyshire rocks were submarine flows in an area that was undergoing slow and prolonged subsidence. Like both spilites and mugearites, their structure is

[1] 'Albitization of Basic Plagioclase Felspars' Geol. Mag. dec. 5, vol. vi (1909) p. 251.

[2] *Ibid.* p. 253.

trachytic and they are rich in alkalies. They are, however, differentiated from the spilites of Cornwall by their abundant content of olivine and the presence of orthoclase. On the other hand, these features are characteristic of the mugearites.

Pillow-structure, again, has not been recorded among the Derbyshire lavas, but this feature is probably dependent on accidental or local circumstances. Mr. C. Reid & Mr. H. Dewey [1] have suggested that it may, perhaps, result from some special physical capacity for retaining bubbles of gas, and be quite independent of chemical composition.

It is clear therefore, in view of the characteristic features of the Derbyshire lavas described above, that, while they are intermediate geographically between the spilites of the South-West of England and the mugearites of the Lothians, they are also intermediate in character. Their structure and field-relations appear to me to associate them, on the whole, more closely with the former than with the latter, and, in view of their outstanding peculiarity, it is suggested that they may be appropriately termed potash-spilites.

It is interesting to note the striking resemblance between the spilitic lavas of Derbyshire and some of the rocks of similar age associated with the Carboniferous Limestone of the Bristol district,[2] which appear to be also of spilitic type. The preponderance of potash over soda is as marked there as in the Derbyshire lavas. The average of five analyses of the Bristol rocks shows the following percentages:—potash = 5·028, soda = 0·854.[3] There, too, as in Derbyshire, the rocks of spilitic type are associated with true basalts.

III. The Associated Rocks.

Just as the mugearites of Skye are associated with the Roineval dolerites,[4] those of the Lothians with olivine-basalts,[5] and the spilites of Devon and Cornwall with albite-diabases,[6] so, too, in Derbyshire, magmatic differentiation has produced similar results which are seen in the association of the spilites of that county with olivine-basalts. These have labradorite or a more basic species for their dominant felspar; but, for the reason already noted, there is no object in describing them here in detail.

The close association of spilites with jaspers and cherts, the

[1] Q. J. G. S. vol. lxiv (1908) p. 268.

[2] S. H. Reynolds, 'Further Work on the Igneous Rocks associated with the Carboniferous Limestone of the Bristol District' Q. J. G. S. vol. lxxii (1916–17) pp. 23–41.

[3] *Ibid.* p. 38.

[4] 'The Tertiary Igneous Rocks of Skye' Mem. Geol. Surv. Scotland, 1904, pp. 262–64.

[5] 'The Geology of East Lothian' *Ibid.* 1910, pp. 122–23.

[6] H. Dewey & J. S. Flett, 'On some British Pillow-Lavas & the Rocks associated with them' Geol. Mag. dec. 5, vol. viii (1911) p. 206.

latter often said to contain radiolaria, is well known. Sir Archibald Geikie[1] has pointed out this association in the case of pillow-lavas in such widely scattered localities as Cader Idris, the Lizard, the southern flanks of the Scottish Highlands, the North of Ireland, Saxony, and California. Mr. Dewey & Dr. Flett[2] have recorded the constant association of the Cornish spilites with radiolarian cherts, which they ascribe to the escape and decomposition of the soda-silicates in the igneous rock, whereby silica would become available for assimilation by the radiolarian plankton.

The physical conditions of the Carboniferous Limestone sea were doubtless, in general, unfavourable to the development of organisms requiring silica for their tests; but an analogue to the Cornish cherts is to be found in the silicified limestone or quartz-rock, formed by the replacement of carbonate of lime by silica, which so often occurs in Derbyshire in the areas of former volcanic activity. These rocks have been described by Dr. Bemrose,[3] and he attributes their occurrence to the action of deep-seated thermal waters holding silica in solution. The liberated silica, which would seem to be a necessary product of the intense alteration that the spilitic lavas have undergone, would probably, unless it were borne away by currents, contribute to this result. Volatilized silicates held in juvenile gases, the later efforts of volcanic energy, would also contribute abundant silica, which would be available for the formation of quartz-rock. Ste.-Claire Deville and other investigators have shown that 'emanations of carbon dioxide mark the dying-out of the volcanic energy,'[4] and it seems probable that the reactions originated by these components of juvenile gases would effect the metasomatism in question.

Instances of the occurrence of quartz-rock in the immediate neighbourhood of vents may be seen at Bonsall, close to the Ember-Lane vent; and at Ashover directly over the tuff of that locality. Near Bakewell, in close proximity to the Crackendale vent, there are thick deposits of chert which may, almost without doubt, be ascribed to similar agency. The same observation applies to the chert which occurs so abundantly in the neighbourhood of Castleton, again in close proximity to the scene of volcanic activity. In the limestone of the Crich inlier there are thin partings consisting entirely of microscopic crystals of quartz.

Evidence in support of the view that the metasomatism resulting in the Crackendale type of chert is due to agents of volcanic origin may be found (apart from the fact that it appears to occur always in the area of former volcanic activity) in the presence of streaks and patches of crystalline calcite and fluorspar embedded in the chert, and also in the development, in cavities, of quartz-crystals

[1] 'Ancient Volcanoes of Great Britain' vol. i (1897) p. 193.
[2] Geol. Mag. dec. 5, vol. viii (1911) p. 245.
[3] Q. J. G. S. vol. liv (1898) pp. 169–82.
[4] See F. W. Clarke: 'The Data of Geochemistry' Bull. U.S. Geol. Surv. No. 616, 3rd ed. (1916) p. 262.

such as are never seen in the normal black chert so abundant in nodules and thin layers in the upper beds of the Carboniferous Limestone of Derbyshire. In the Crackendale chert-beds, too, all the original organisms of the limestone appear to have been entirely destroyed, although in the limestone above and below the chert fossils are abundant. The chert-beds at the Holme-Bank Mine have an average thickness of 4 feet, and the rock is white or grey in colour: it is mined for use in the Potteries.

IV. Petrogenetic Considerations.

The form of alteration to which the Derbyshire spilites have been subjected obviously is quite different from that which results from ordinary weathering, and appears to be clearly in the nature of autometamorphism. All the available field-evidence that I have hitherto noted tends to show that the spilitic rocks generally underlie (in the same bed) those of more basaltic type, and it is sometimes possible to observe a progressive upward variation. This has already been noted in the description of the lavas on Knot Low and in Tideswell Dale.

These observations agree with those recorded by other investigators, from Charles Darwin [1] (more than seventy years ago) to Prof. P. Marshall [2] in his paper read before the Geological Society in May 1914, to the effect that, where alkaline and calcic lavas proceed from the same orifice, the former have generally been erupted first.

It is not claimed that the Derbyshire spilites are of extreme alkaline type; but it is suggested that, in considering their genetic relations to the associated basalts, we may premise a magma of which the upper part was richer in gases and in the more easily sublimable constituents, including the alkalies, than the remainder, and that, as this upper portion was drawn off, the later erupted material would tend to become increasingly calcic. The constantly vesicular nature of the spilites is sufficient proof of the presence of a large amount of gases and residual water.

That no general stratification of the magma, due to the action of gravity, took place prior to eruption is, however, clear from the fact that the earliest flows, the spilites, always contain a notable proportion of the first-formed minerals—olivine and iron-ores.

Without entering on the vexed question of the origin of alkaline rocks in general, on which so much has been written of late years, I may point out that the relative enrichment in alkaline constituents of the upper part of the magma, postulated above, is probably assignable to the upward passage through the magma of gases carrying with them a considerable portion of the alkalies

[1] 'Geological Observations on the Volcanic Islands' 1844, p. 118.
[2] Q. J. G. S. vol. lxx (1914) pp. 382–406.

in a volatile state. Prof. R. A. Daly[1] cites strong corroboration of his view that

'the abundant soda of a spilite has been concentrated from an underlying mass of normal basaltic magma'

by gaseous transfer of the albite molecule. Dr. F. W. Clarke[2] is also of opinion that

'the magmatic vapours must exert an important influence upon the process of differentiation, for they tend to accumulate in the upper part of a lava column or reservoir and to modify its properties locally.'

A further consideration, which appears to have an important bearing on the evolution of the spilites, is the effect of the physical environment of a submarine flow. It is generally recognized that the pressure of the superincumbent mass of water on the molten rock would effect the rapid formation of a thin crust on its surface, with the twofold result that its internal heat would be retained longer than in the case of a subaërial flow, and the release of the volatile constituents would be impeded.

The presence of hot alkaline solutions thus retained and circulating among the earlier-formed minerals affords a ready explanation, as has been noted by other observers, of the intense alteration seen in the spilites. Post-volcanic or juvenile emanations have also been invoked, but retained residual solutions, especially in the case of outcrops far removed from any recognizable vent, seem quite sufficient for the purpose.

It has been already pointed out that the basalts, which were erupted later than the spilites, are often beautifully fresh, although they have, of course, been subjected to the same external influences since eruption as the spilites. This affords further evidence that the alteration of the spilites cannot be due to weathering. It appears, rather, to be the final stage of consolidation.

The infilling of the vesicles presents features which, it is suggested, may be referred to the prolonged retention of a high temperature in the lava after effusion. It has already been stated that the vesicle-minerals are chlorite, albite, quartz, chalcedony, calcite, and dolomite. Seeing that augite was one of the latest minerals to consolidate, it is probable that the hydrated residue contained augite-forming bases, and thus the earliest-formed chlorite, the lining of the vesicles, which differs widely in character from the helminth and delessite formed at later stages, may, perhaps, be regarded as a primary mineral. This seems to be the view advocated by Mr. James Strachan.[3]

The amygdaloidal albite, too, may also be regarded as a primary

[1] 'Igneous Rocks & their Origin' 1914, p. 339.

[2] 'The Data of Geochemistry' 3rd ed. (1916) p. 311.

[3] 'The Carnmoney Chalcedony: its Occurrence & Origin' Proc. Belfast Nat. Field Club, vol. ii (1906).

mineral, since there can be little doubt that the hydrated residue contained all the elements necessary to its formation. The occurrence of amygdaloidal albite is somewhat rare: in the Tideswell-Dale rock, when it occurs in the vesicles, this albite forms the entire infilling, with the exception of the thin chloritic lining.

The other infilling minerals are all clearly of secondary origin, resulting from the breakdown of the ferromagnesian constituents. They are, moreover, all minerals that may be formed at fairly high temperatures, and it is noteworthy that no hydrated minerals that are formed at lower temperatures than albite, such as zeolites of various species, and prehnite, are present (so far as my observation goes) in any of the Derbyshire lavas, whether spilites or basalts. The synthesis of both albite and orthoclase has been effected by various investigators at about 500° C.[1]

Mr. W. F. P. McLintock[2] has shown that in the vesicles of Beinn Fhada (Mull) the order of deposition, apart from chlorite, which there, too, may be formed at any stage, was: albite, epidote, prehnite, scolecite. These vesicles were evidently filled under conditions of falling temperature; for, with rising temperature, occasioned by an intrusion of granophyre, the metamorphic changes in lime-bearing silicates resulted in the production of minerals in the reverse order: scolecite, prehnite, epidote, garnet. Since all the elements necessary to the formation of minerals of the zeolitic class so frequently found in basalts were undoubtedly present in the residual solutions of the Derbyshire lavas, either as primary constituents thereof or as alteration-products of the earlier-formed minerals, the inference seems to be justified that the consolidation and the autometamorphism of the Derbyshire spilites were both completed before the temperature fell much below 500° C.

V. Analyses.

Analyses of two of the spilitic lavas of Derbyshire are given on p. 22 (Nos. IV & V) and partial analyses of a third (Nos. VI & VII). For comparison, analyses of a mugearite and two spilites are also quoted. Such intensely altered rocks as these cannot, of course, be expected to show the composition of the original rock. Nevertheless, it is clear that we are dealing here with essentially basic rocks rich in alkalies, especially potash, but much altered with production of carbonates and hydrated secondary material. If we assume the carbon dioxide to be combined with lime in the form of calcite, an assumption which is borne out by the microscope, it will be seen that there is very little lime left for lime-felspar.

[1] See C. Dœlter, 'Minerogenese & Stabilitätsfelder der Minerale' Tschermak's Min. Petr. Mittheil. vol. xxv (1906) p. 103; also F. W. Clarke, 'The Data of Geochemistry' Bull. U.S. Geol. Surv. No. 616, 3rd ed. (1916) p. 366.

[2] 'On the Zeolites & Associated Minerals from the Tertiary Lavas around Ben More (Mull)' Trans. Roy. Soc. Edin. vol. li (1915) pp. 24–30.

	I.	II.	III.	IV.	V.	VI.	VII.
SiO_2	49·24	47·56	40·55	43·13	47·03		
Al_2O_3	15·84	14·27	16·65	23·25	22·45		
Fe_2O_3	6·09	1·63	1·13	1·87	7·00		
FeO	7·18	6·80	9·46	4·81			
MnO	0·29	0·30	0·20	trace	...		
MgO	3·02	4·90	5·20	6·50	8·79		
CaO	5·26	10·95	6·06	5·58	2·92		
Na_2O	5·21	4·61	4·76	3·60	2·63	0·82	1·2
K_2O	2·10	0·27	0·27	3·04	4·55	6·59	5·5
TiO_2	1·84	2·40	2·95	not est.	not est.		
CO_2	...	2·95	7·85	3·50	1·90		
H_2O (hygrosc.)	1·08	0·42	0·27	1·06	...		
H_2O (comb.)	1·61	2·65	3·89	3·76	3·65		
Other constituents	1·77	0·54	0·90	...	...		
Totals	100·53	100·25	100·14	100·10	100·92		

I. Mugearite, Druim na Criche, Skye (W. Pollard). 'The Tertiary Igneous Rocks of Skye' Mem. Geol. Surv. Scotland, 1904, p. 263.

II. Spilite, Tregedden, South Cornwall (E. G. Radley). Quoted from H. Dewey & J. S. Flett, 'On some British Pillow-Lavas & the Rocks associated with them' Geol. Mag. dec. 5, vol. viii (1911) p. 206.

III. Spilite, Devonport Workhouse Quarry (W. Pollard). 'The Geology of the Country around Plymouth & Liskeard' Mem. Geol. Surv. 1907, p. 97.

IV. Spilitic lava, Tideswell Dale (E. Sinkinson).

V. Spilitic lava, Knot Low, Millers Dale (E. Sinkinson).

VI. Spilitic lava, Masson, Matlock. Partial analysis (E. Sinkinson).

VII. Spilitic lava, Masson, Matlock. Partial analysis (C. S. Garnett),

VI. The Tuffs.

Although the scope of this paper is limited to the lava-flows, it is interesting to note that the tuffs, under the microscope, are not infrequently seen to contain felspar-crystals with straight extinction. Dr. Bemrose [1] records the occurrence of such felspars at the following tuff outcrops: Cressbrook Dale, Monk's Dale, Crackendale, Ember Lane, Grange Mill, Woodeaves Vent. He also notes the presence in specimens from Grange Mill of

'a felspar-like material here and there in the lapilli which is biaxial, and may be secondary albite.' [2]

Water-clear, untwinned felspars also occur in some of these tuffs. On the assumption that, when explosive action occurs, it takes place at the commencement of the volcanic episode, we have thus further evidence that the alkalies were to some extent concentrated in the upper part of the magma.

[1] Q. J. G. S. vol. l (1894) pp. 629-38.
[2] *Ibid.* p. 635.

VII. Summary of Conclusions.

(1) The lavas of Derbyshire, which are all of Lower Carboniferous age, embrace rocks of spilitic or mugearitic type and basalts. Both types have been derived from a common magma. The field-relations hitherto ascertained indicate that, when they occur in association, the spilitic rocks always underlie, and may grade upwards into, the basalts.

(2) The differentiation was effected by the partial concentration, prior to eruption, of the alkaline constituents in the upper part of the magma, whither they were probably carried in a volatile state by the upward movement of gases in the magma.

(3) The intense alteration which the spilitic rocks have undergone was effected shortly after extrusion by hot residual solutions belonging to the lava itself, and not by post-volcanic emanations or weathering agencies.

(4) The deposits of quartz-rock and chert, which frequently occur in Derbyshire in the neighbourhood of vents, are probably the result of volcanic emanations of which it is difficult to define the precise composition. There appears to be no doubt that they contained silicates and carbon dioxide in solution, and other substances may have been present. Silica liberated from the lavas as a result of pneumatolytic alteration may also have contributed to the same result.

Discussion.

The President (Dr. A. Harker) welcomed this contribution to the petrology of the Carboniferous lavas. The interesting alkaline types described had been hitherto neglected, owing partly to a tendency to select for study the fresher-looking material. It would appear that in Lower Carboniferous times the British area included two petrographical provinces, both characterized by rock-types rich in sodic felspars, but having different histories. The southern or Cornish province was an old-established one, and was spilitic: the Somerset lavas must be included here. The northern province represented a reaction from the very different Caledonian *régime*, and was marked by the prominence of olivine-basalts and mugearites, with some soda-trachytes: here belong the Scottish and Irish districts with the Isle of Man. In Derbyshire, occupying geographically an intermediate situation, the volcanic rocks seem to be mainly of Scottish types, but with spilitic affinities indicated in some of the occurrences.

Mr. E. B. Bailey queried the application of the term 'spilitic' to a suite of rocks in which pseudomorphs after olivine are commonly found. He thought that the decomposed lavas of Derbyshire might be compared perhaps with albitized basalts and mugearites from the Scottish Carboniferous, rather than with the numerous occurrences of spilites described by Dr. Flett from

other formations. The problem of albitization had attracted considerable attention from British geologists since Mr. Grabham noticed albitization among the Scottish Carboniferous lavas. A notable recent contribution was that of Mr. McLintock, who had studied the Tertiary propylites—to use the late Prof. Judd's nomenclature—of the island of Mull. It was best to discuss the origin of albitization in every case upon the local evidence. In connexion with the present paper, which added considerably to our knowledge of the Derbyshire volcanic rocks, it was important to know whether the accompanying analyses could be fully relied upon.

Dr. A. H. Cox wished to congratulate the Author on the results of the investigations. He had been particularly interested in hearing these results, since they confirmed opinions at which he had previously arrived from theoretical considerations. The President had already referred to the Derbyshire rocks as being intermediate in character between the Lower Carboniferous lavas of Devon and Cornwall on the one side, and those of Scotland on the other. The stratigraphical conditions were also intermediate. The lavas of the West of England were extruded in an area which, having undergone prolonged subsidence, was geosynclinal in character, and the rocks were typically spilitic. On the other hand, the Lower Carboniferous of Scotland was a shallow-water formation, implying only a limited amount of subsidence, and the lavas were typically basaltic, sometimes, it was true, showing a certain amount of albitization. Opposed to this was the Lower Carboniferous of Derbyshire—a massive limestone formation, evidently deposited in deeper water, implying a greater degree of subsidence, though not by any means to such a degree as that which had obtained in the West of England. It was to be expected, therefore, that the Derbyshire lavas, while very largely basaltic, would yet show a closer approach to the spilitic type than was manifest in the case of the Scottish rocks. The whole question of a possible connexion between the type of earth-movement and the composition of the igneous rocks produced during such movement was still an open one, and papers such as the Author's were most valuable as furnishing the data by means of which this important subject could be investigated.

The Author, in a brief reply, desired in the first place to thank the President and Fellows for their kind reception of his paper.

In regard to Mr. Bailey's view that it was misleading to call an olivine-bearing rock a spilite, he pointed out that, since the spilites appear to be derived from the basalts, and since there are both olivine-basalts and basalts without olivine, there seemed to be no valid reason why there should not also be olivine-spilites and spilites without olivine.

It had been a question of some difficulty whether the Derbyshire rocks should be placed with the spilites or with the mugearites: he thought, however, that, in view not only of their structure but also of their physical environment, they came nearer the former

than the latter. The Carboniferous Limestone was no doubt a deeper-water formation than the Calciferous Sandstone; and the conditions obtaining in Derbyshire, when the spilites of that area were erupted, probably more nearly approached those of Cornwall at the same period than those of the Lothians. He deprecated unnecessary additions to the nomenclature of rocks, and thought that, if the term potash-spilites were used for the Derbyshire rocks, their outstanding peculiarity would be sufficiently indicated.

With regard to the analyses, he quite agreed as to their importance, and had every confidence in their accuracy.

In reply to Dr. Cox, he agreed that, although no active folding or faulting took place when the Derbyshire rocks were erupted, there was clearly a state of slow and prolonged subsidence, although not to the same extent as in Cornwall, and this might have been a factor in the evolution of the rocks.

3. *The* Morphology *and* Development *of the* Ammonite Septum.

By Henry Hurd Swinnerton, D.Sc., F.G.S., Professor of Geology & Geography in University College, Nottingham, and Arthur Elijah Trueman, M.Sc. (Read April 18th, 1917.)

[Plates II–IV.]

Contents.

I. Introduction.

Several years ago one of us noted with particular interest the appearance of the sutures upon some badly-weathered ammonites. They were characterized by an absence of frilling and a simplicity of curvature strongly suggestive of the early stages in development. A preliminary enquiry was immediately made into the development of the sutures of *Dactylioceras*, and into the changes produced in the adult suture by filing the surface away in imitation of the process of weathering. This made it evident that the similarity already noted was not merely superficial, but had a widely-extended significance. It was with the view of establishing the extent and limitations of this similarity, as determined by variations in the shape of the whorl in different ammonites, that the present investigation was undertaken.

As the work advanced, the problem resolved itself into a study of the morphology and development of the septum as opposed to the suture-line. The value of the latter has long been recognized, and a distinguished succession of workers, including Sowerby, Hyatt, Neumayr, and Buckman, have made very effective use of it in solving problems of ammonite affinities. On the other hand, and apart from the suture-line, the septum itself has been comparatively neglected, and much of the information which exists concerning it must be gleaned from figures, frequently undiscussed.

There has also been a limited discussion upon the mechanical conditions which have been concerned in modelling the septum, and upon the relations of newly-formed septa to their predecessors.

II. Methods of Investigation.

The chief obstacle to the study of the septum is the difficulty experienced in isolating the casts of successive chambers in such a way as to show a septal face with all its marginal frilling complete. This difficulty increases as the frilling becomes more complex. It is very seldom that a specimen breaks naturally in such a way as to show a complete septum, for the minor, if not the major, frills are almost invariably broken.

The septa shown in Pl. III, figs. 1, 6, & 7, were cleaned with acid and tools, and supplied much useful information. The alternative method was to file away the superficial portions of a whorl in successive layers. This brought to view a series of sections of the septa cut approximately parallel to the periphery. Such sections are hereinafter referred to as septal sections.

To secure accuracy in working, much use was made of the instrument figured in Pl. II, fig. 1, and shown in the accompanying text-figures (1 & 2, pp. 28–29) in plan and elevation.

This was designed with the expert assistance of Dr. P. E. Shaw, of the Physics Department of University College, Nottingham. It consisted of two parts. The one was a microscope with micrometer eyepiece and graduated rack-scale, of the kind commonly used in physical laboratories. The other consisted of a graduated turn-table (fig. 2 *a*) mounted on another table (*b*) which could travel horizontally. This latter had one edge provided with a vernier and laid against a fixed horizontal scale. Above the table was a double-pointed needle (*c*) held up in the position of rest shown in Pl. II, fig. 1, by a lever (*d*) actuated by a spring (*e*). The needle passed loosely through the lever, and rested on it by means of a collar (*f*). When the lever was pressed down the needle was left free to fall. As it was very light, a spring (*g*) was inserted which, by pressure on a collar (*h*) near the lower end, ensured a certain but gentle contact of the point with the surface of the table, or of the object of study. When the lever was released, the needle was at once lifted by it to the position of rest. The microscope was focussed upon the upper point of the needle, and its precise position, as recorded in the micrometer eyepiece and on the rack-scale, was noted. The amount of drop of the needle on to the table, or on to different points of the surface of an object, could then be easily registered—for small movements by means of the eyepiece alone; for large ones, by the rack-scale.

In obtaining the measurements for producing the contoured plan of a septum (fig. 4, p. 32) the specimen was securely fastened, with the septal face upwards, on the centre of the turn-table. This being caused to travel horizontally, a series of heights, or depths, was taken at definite intervals along one diameter of the septum.

Fig. 1.—*Plan of the instrument used in surveying and levelling the surfaces of septa and whorls.*

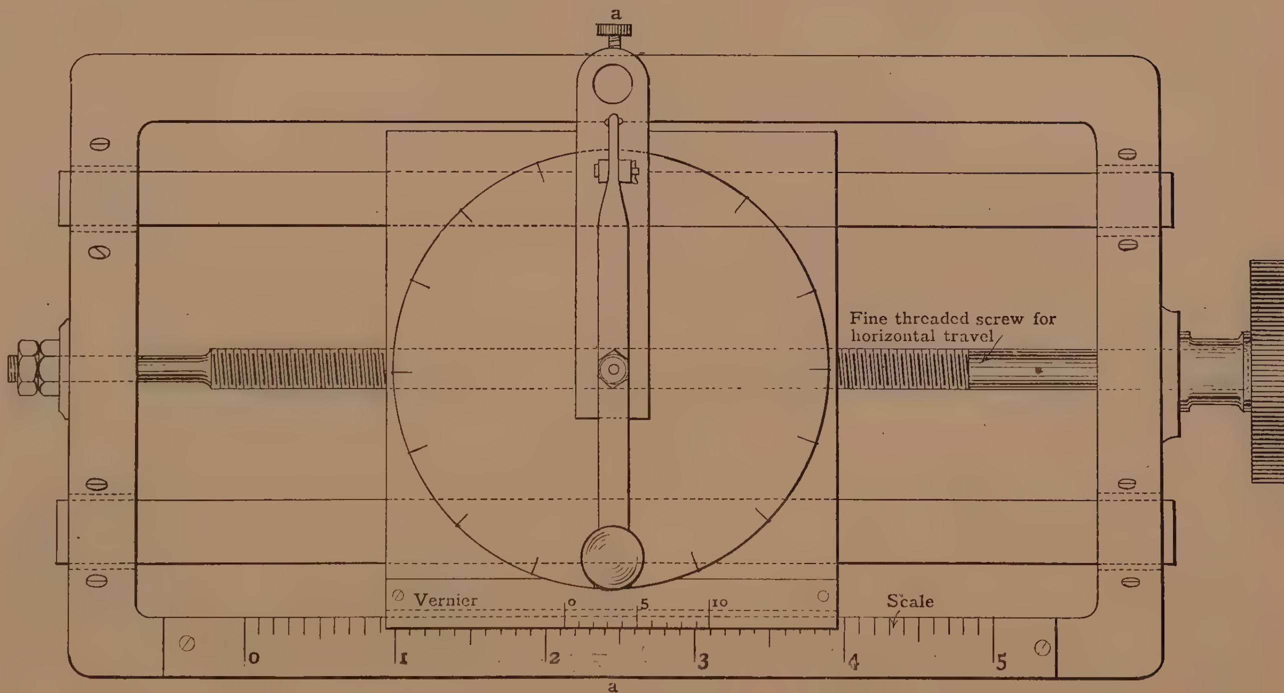
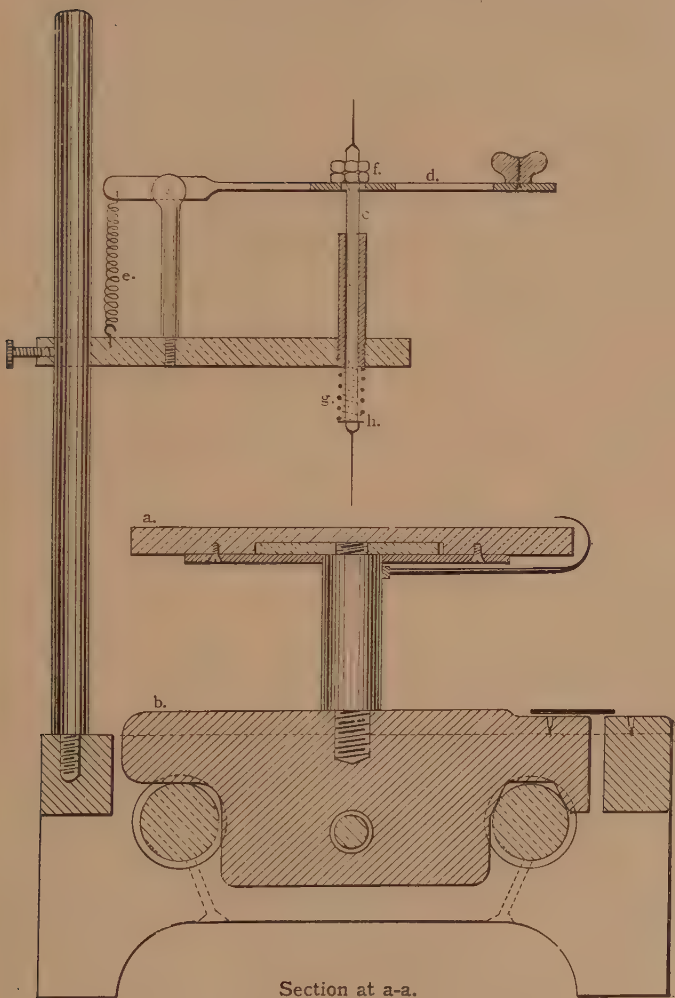


Fig. 2.—*Section of the instrument used in surveying and levelling the surfaces of septa and whorls.*



Section at a-a.

The table was then rotated through a certain number of degrees, and another diameter was brought into line with the direction of travel. This process was repeated until readings had been taken along a sufficient number of radial lines to allow of a contoured plan being made. Though this plan proved of great value, it could not be relied upon to record certain details, inasmuch as any portion of the septal surface which tended to be an 'under-cut' could not be registered by the vertically moving needle.

In the preparation of a plan (figs. 11, 14, & 17, pp. 44, 46, & 49) showing the precise position of successive surfaces produced by filing, the following procedure was adopted. A portion of an adult whorl, containing at least one septum, was isolated, and the ends were ground flat and polished along a plane parallel to that of the septum. The specimen was then placed on the turn-table, with one of its ends pressed against the polished side of a metal block, fastened so that the plane of the septum lay in the direction of travel, and under the point of the needle. The rounded venter of the whorl was then made to pass under the needle, and readings were taken at regular intervals by means of the scale and vernier. This was repeated for the side and the dorsum. The surface of the whorl was then carefully filed away over the area occupied by the suture-line. Within the zone of complicated frilling, in a specimen of the size of *Dactylioceras commune*, a depth of only ·25 mm. was removed; but in deeper and less complicated regions of the septum this was increased to ·5 mm. or even more. At each level a series of readings was taken, and the corresponding profile of the filed surface was made and introduced into the plan. With small ammonites the whole specimen was used, and a wax or plaster mould was made to hold it.

For the purposes of general systematic work, upon a large quantity of material, the methods just described involve too much labour and, incidentally, the whole of the septum may be lost by filing. Such methods were necessary in order to test the value of septal sections of one septum for the first time, and all the results recorded in the following pages were obtained by them. For most purposes, it will suffice if the worker takes a portion of a whorl containing not less than eight septa, and files it into a truncated cone or, better still, into a series of steps (Pl. II, figs. 3 & 4). The successive septa will be cut at increasing depths, and will show most of the salient features seen in a series of sections made from one septum. As a rule, the differences between successive septa will not be great enough to vitiate the results seriously (compare Pl. II, fig. 4 with text-fig. 10, p. 43), and at the same time the series can be preserved for reference.

The camera lucida was used for drawing the sutures and septal sections of small fossils. The whorl was turned to show successive portions the drawings of which were subsequently pieced together. Sutures of larger specimens were reproduced in the manner suggested by Mr. S. S. Buckman:[1] namely, by painting the chamber behind the suture and then tracing the latter.

[1] 'Inf. Ool. Amm.' Monogr. Palæont. Soc. 1894, p. 380.

III. Materials used in the Investigation.

Three species of ammonites were chosen for the main part of this enquiry, namely:—

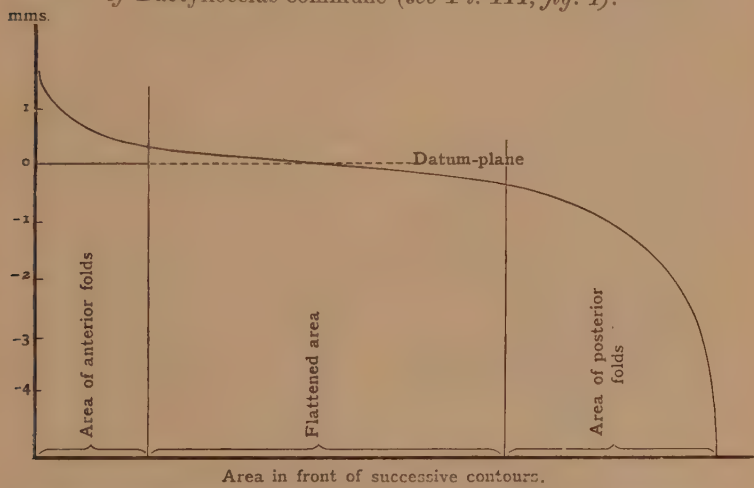
Dactylioceras commune, because it had what may be defined as a normally shaped whorl: that is, neither depressed nor compressed to any marked degree.

Sphæroceras brongniarti, as an example of a form possessing a depressed whorl.

Tragophylloceras loscombi, as representing forms possessing elevated and compressed whorls.

In the two former the development of the suture was worked out in the same specimens as those from which the septa used for making septal sections were taken. In the first, a series of septa was also cleaned, while the protoconch and first whorl were reconstructed in wax, and arranged in such a way that the separate chambers could be taken apart and the septa examined.

Fig. 3.—*Graph showing the average profile of the adult septum of* Dactylioceras commune *(see Pl. III, fig. 1).*



We are indebted to Mr. W. D. Lang, F.G.S., of the British Museum (Natural History), for samples of the third, and we relied for the sutural development upon the figures of Mr. L. Spath,[1] which we reproduce here in fig. 12 (p. 46). The details of other material will be given below.

IV. The Morphology of the Adult Septum.

The consideration of the morphology of the septum may be approached from a study of the contoured plan (fig. 4), which was made from a cleaned septum of an adult *Dactylioceras commune*.

[1] 'On the Development of *Tragophylloceras loscombi*' Q. J. G. S. vol. lxx (1914) p. 341.

The septum was 14 mm. broad, and measured 9·25 mm. from dorsum to venter. The datum-plane taken passed through the centre of the ammonite at right angles to the plane of coiling, and touched the septum tangentially in its median line.

The general form assumed by septa has been aptly described by S. P. Woodward[1] as

> 'nearly flat in the middle and folded round the edge like a shirt-frill, where they abut against the outer shell-wall.'

The anterior folds are referred to as saddles and the posterior as lobes. The extreme antero-posterior range from crest of saddle to trough of lobe was 6·5 mm.

Fig. 4.—*Contoured plan of the adult septum of* Dactylioceras commune *(see Pl. III. fig. 1).*

[The shaded portion is the flattened area; the thick lines represent the posterior folds, or lobes: the thin lines represent the anterior folds, or saddles. The contours are drawn at intervals of 0·25 mm.]

The graph shown in fig. 3 (p. 31) was made by finding the relative areas of septum in front of successive contour-lines. It shows that nearly 52 per cent. of the area of the septum lies between contours only 0·75 mm. apart. This portion of the septum, with its extensions into the folded region, is shown with dotted shading in fig. 4. This flattened area is concentrated chiefly in the centre of the septum, and coincides approximately with the datum-plane. The central area is crossed by very slight undulations, which unite the corresponding folds of the opposite sides, or of the venter and dorsum, in all three genera. In highly compressed or depressed ammonites these undulations become more or less strongly developed folds.

From the graph it is also apparent that the area occupied by the posterior folds is much greater than that occupied by the anterior folds, and further that the former are more acute than the latter. It thus appears that the septum as a whole is convex forwards, as stated by J. F. Blake[2]; although it should be noted that sections across the septum in

[1] 'Manual of Palæontology' 1872, p. 286.
[2] 'The Yorkshire Lias' 1876, p. 263.

different directions are here convex there concave. Branco[1] and Hyatt[2] both observe that in median sections of ammonites the profile of the septum, passing as it does along the troughs of the dorsal and ventral lobes, necessarily appears convex forward. On the other hand, it may be remarked that profile sections along the crests of individual saddles are concave forwards. Thus the form of an anterior fold of the septum is comparable with that of a horse's saddle, or with the heterocœlous articular surface of a bird's cervical vertebra, since sections along the crest, and at right angles to it, are concave, and convex respectively.

NOTE.—J. F. Blake suggested that the forward convexity of the septum is evidence of pressure from behind the animal, and that the saddles represent parts of the edge which have yielded to the pressure. In more recent work Pfaff[3] also concludes that the form of the septum has been determined largely by pressure upon the posterior part of the animal. Probably, as in the Pearly *Nautilus* (Willey[4]), the chambers of the shell were filled with gas secreted by the veins of the mantle. In ammonites the vigour of secretion may have been so great that the gas exerted sufficient pressure upon the soft mantle to make it bulge forward, while the septum was being deposited. The formation of a new septum must always have been preceded by a period of rapid evolution of gas. Perhaps the pressure thus produced helped the forward shifting of the posterior end of the long worm-like body of the ammonite.

In all three types of ammonites considered, the axes of the folds are always approximately at right angles to the whorl-surface (Pl. III), and they maintain this relation throughout all the changes in shape of the whorl which take place during development or during the distortions associated with asymmetry (Pl. IV, figs. 1, 4, & 9).

Each pair of folds behaves independently of the others. Thus, in the development of the septum of *Dactylioceras commune* the axis of the internal saddle is at one stage almost continuous with that of the external saddle (Pl. III, fig. 3); but as, during development, the whorl increases in height, it comes into a similar relation with the first lateral saddle (Pl. III, figs. 1 & 2). The same independence is manifested also in the development of the septum in *Tragophylloceras*.[5]

This independence finds further expression in the variations of arrangement of the folds according to the shape of the whorl. When this is round, as, for example, in *Lytoceras*, they radiate from a central point; when it is impressed dorsally, as, for instance, in *Dactylioceras* and *Sphæroceras* (Pl. III, figs. 1 & 7), the internal folds come into relation with the corresponding external saddles, and the number of dorsal and ventral elements is nearly equal; when it is compressed, as in *Tragophylloceras* (Pl. III,

[1] 'Beiträge zur Entwickelungsgeschichte der Fossilen Cephalopoden' Palæontographica, pt. 2, vol. xxvi (1879–81) p. 50.

[2] 'Genesis of the Arietidæ' Smithson. Contrib. to Knowledge, No. 673, 1889.

[3] 'Form & Bau der Ammonitensepten & ihre Beziehungen zur Suturlinie' Jahresb. des Niedersächs. Geol. Verein, vol. iv (1911) p. 208.

[4] 'Contribution to the Natural History of the Pearly *Nautilus*' Zool. Results .... New Britain, New Guinea, &c., pt. vi, 1902, 4to. Cambridge.

[5] L. F. Spath, Q. J. G. S. vol. lxx (1914) pl. xlix.

fig. 6), the ventrally situated folds of the external series come into line with their fellows of the opposite sides, and consequently the elements of the venter exceed those of the dorsum by the number of folds which thus cross the central area.[1]

V. Terminology of Lobes and Saddles.

Some of the existing terminologies for lobes and saddles of the suture-line cannot be adopted for the present purpose, because they are to a great extent arbitrary. Thus the term superior, as applied to the first two lateral saddles, although it fits in with the accepted conventional method—used even in our own figures—of representing the septum, is quite wrong when the septum is correctly placed with its venter downwards, in the attitude which it is believed to have assumed when the animal was alive.

The terminology suggested by Mr. S. S. Buckman[2] is most nearly in accordance with the facts of development, and will be adopted here. He gives the name of external saddles to the pair on each side of the ventral lobe; and uses the term lateral for the others. The difference thus implied is a real one: the external saddles originate from the large median saddle ('aussensattel' of Branco) of the first septum by the appearance upon its crest of a median lobe (Spath, *op. cit.* 1914, p. 341; A. E. Trueman[3]). The lateral saddles, on the contrary, appear as simple folds on the umbilical angle, and travel thence towards the venter (Pl. III; and Spath, *op. cit.* pl. xlix, figs. 2 *a* & 2 *b*).

The development of the folds on the dorsum apparently follows the same lines as those just laid down for the venter. Thus, the first septum shows occasionally a median saddle (fig. 12 *a*, p. 46; Spath, *op. cit.* pl. xlviii, fig. 2 *c*). In the second septum this has given place to a median dorsal lobe flanked by the internal saddles. The remaining elements appear at the umbilical angle, and travel towards the median dorsal line (see figs. 9 *c*, *d*, & *e*, p. 42; 12 *c* & *e*, p. 46; and 15 *c*, *d*, *f*, & *g*, p. 48).

Although the distinction into laterals and auxiliaries may be convenient for descriptive purposes, it does not correspond to any morphological difference between the folds—inasmuch as the auxiliaries also appear for the first time as simple folds on the umbilical wing of the septum, and travel towards the venter or towards the dorsum, as the case may be. Moreover, the auxiliaries of one ammonite may correspond to the laterals of another. Thus, development shows that the large second lateral of *Tragophylloceras loscombi* is the strict homologue of the small first auxiliary of *Dactylioceras*.

[1] The septal aponeurosis of ammonites does not seem to have been so well developed as in *Nautilus*. In them the fibres were apparently isolated and attached to the shell along a wavy line at points indicated on the suture-line by denticles. Pressure upon a membrane thus attached by its margin must produce folds at right angles to the periphery.

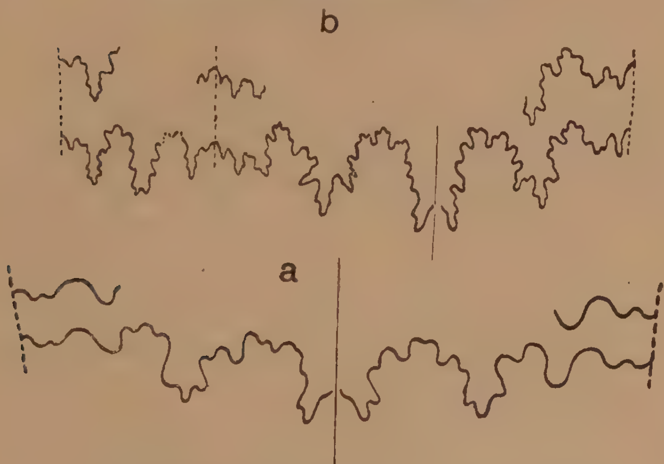
[2] 'Yorkshire Type Ammonites' vol. i (1909–12) p. ix.

[3] 'The Lineage of *Tragophylloceras loscombi*' The Naturalist, 1916, p. 222.

VI. The Formation of the Septum.

Evidence bearing upon the mode of deposition of the septum is scanty. In an adult specimen of *Dactylioceras commune* from Grantham, the last septum was found to be only in part secreted. Its suture was clearly visible as a white line at the umbilical angles. Here the secretion of the septum was evidently well-advanced, but elsewhere it could be seen only as a faint dark line—possibly due to a conchiolin membrane. Septal sections seemed to indicate that the septum was incomplete internally; but a definite statement cannot be made, for it had evidently been disrupted when the shell was becoming filled with mud. The evidence shows that the

Fig. 5.—*Last two suture-lines of two ammonites showing the last suture incompletely formed.*



a = *Dactylioceras commune*, Grantham. Diameter = 57 mm.
b = *Polymorphites jupiter*, Old Dalby. Diameter = 18 mm.

secretion commenced in the region farthest removed from the siphuncle. Partly formed septa, showing the same peculiarities, have also been noticed in *Polymorphites jupiter* d'Orbigny (fig. 5 *b*).

The formation of the septum in ammonites seems to have taken place in the same manner as in living *Nautilus*. It has long been known [1] that in the latter the deposition of calcareous matter begins at the sides of the shell, and proceeds towards the siphuncle. Willey (1902) observed further that the secretion of a septum was preceded by the formation of a conchiolin membrane, upon which the calcareous matter was deposited.

The septa, just described for *Dactylioceras* and *Polymorphites*,

[1] F. A. Bather, 'Growth of Cephalopod Shells' Geol. Mag. dec. 3, vol. iv 1887) p. 447.

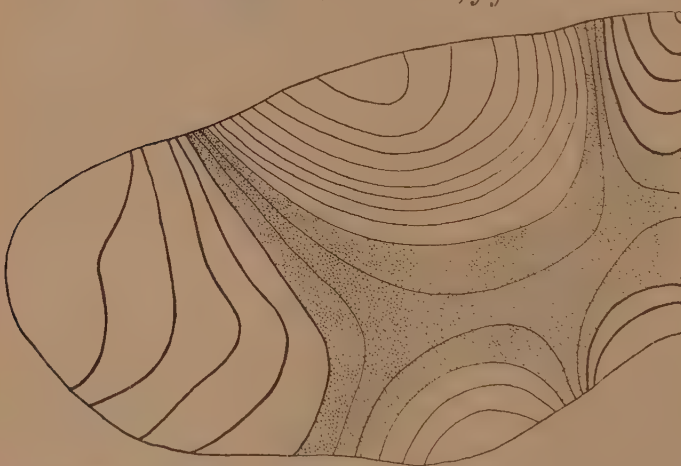
were complete in all sutural details and, though only formed in part, were situated at the normal distance from the preceding septa. These facts run counter to the views of Riefstahl[1] supported by Buckman[2]; and, along with the observations of Willey (1902) upon *Nautilus*, they furnish further support, if such be needed, for those of Bather[3] and Appellöf.[4] According to Riefstahl, the last septum was formed in contact with the previous one, and became separated by the growth of the intervening shell-wall. He based his view upon the microscopical study of the sepion. This, however, is so highly modified that it would not be safe to use it for throwing light upon the formation of the septum of the (comparatively) closely-allied belemnite, still less upon that of the only very distantly-related ammonite.

VII. The Development of the Septum of *Dactylioceras commune*.

(1) The Second Septum.

A wax model enlargement was made of the second septum, and from this a contoured plan (fig. 6) and a graph (fig. 7), like those

Fig. 6.—*Contoured plan of the second septum of* Dactylioceras commune *shown in Pl. III, fig. 4.*



[Explanation as in fig. 4 (p. 32). The contours are drawn at intervals of 0·01 mm.]

already described for the adult septum, were constructed. The

[1] 'Die Sepienschale & ihre Beziehung zu den Belemniten' Palæontographica, vol. xxxii (1886) p. 20.

[2] 'Notes on Nautili & Belemnites' Proc. Geol. Soc. vol. xlvii (1891) p. 165.

[3] 'Shell-Growth in Cephalopoda' Ann. Mag. Nat. Hist. ser. 6, vol. i (1888) p. 298.

[4] 'Die Schalen von *Sepia*, *Spirula*, & *Nautilus*' Kongl. Svenska Vetenskaps-Akad. Handl. vol. xxv, No. 7 (1893) p. 28.

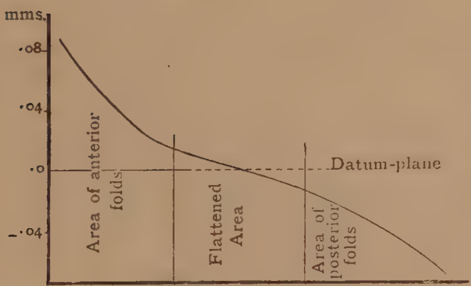
septum itself was 0·95 mm. broad, and 0·22 mm. from dorsum to venter. The extreme antero-posterior range from the crest of the saddles to the trough of the lobes was 0·16 mm. The area shaded in the plan is comparable with the flattened area of the adult, but is relatively much less extensive. It lies between contours 0·03 mm. apart, and occupies 30 per cent. of the area of the septum. On the whole, the septum tends to be concave rather than convex forwards.

It is evident that the septum-secreting portion of the mantle, which was strongly convex at the time of formation of the protoconch and even of the first septum, had already begun to feel the influence of that pressure, which in later life became strong enough to impose upon it a marked concavity. In the more primitive ammonoids, especially the Asellati,[1] the form of the earlier septa proves that this influence did not develop quite so rapidly in them as it did in the specialized forms represented by *Dactylioceras*.

(2) Comparison of the Second with the Adult Septum.

On comparing the second septum of *Dactylioceras* (Pl. III) with the adult septum, it is seen that, apart from the peripheral zone, the latter shows all the essential features of the former, so that, except for the increase in size and flattening of the elements, the major portion of the septum has undergone no significant change during development. The changes already mentioned above: namely, the relative movements of the first lateral saddle as the height of the whorl increases, and the origin of the new lobes and saddles on the umbilical wing of the septum, are confined to the marginal area.

Fig. 7.—*Graph illustrating the average profile of the second septum of* Dactylioceras *shown in Pl. III, fig. 4.*



It must not be supposed, however, that this general agreement of the major portion of the adult septum with the whole of the second septum is due merely to a simple enlargement of the area which secreted the latter. Had this been the case, the siphuncle would have retained the subcentral position of the second septum throughout life. During the growth of the first and second whorls, however, it gradually shifts to the ventral margin, and thus comes to lie within the frilled peripheral zone. In some cases, according

[1] W. Branco, Palæontographica, vol. xxvii (1880) p. 68.

to Branco,[1] the siphon lies near the internal margin of the early septum, as in most latisellate ammonoids; while in certain forms, as, for example, *Goniatites lamed* var. *calculiformis*, it occupies a ventral position from the first. Despite these variations in position of the siphuncle, the development of the septum pursues a definite course. Assuming that there is no actual migration of the siphuncular cord through the substance of the mantle, it may be taken as furnishing a datum-point. It then seems as though a portion of the mantle ventral to this point is withdrawn from taking part in the secretion of the septum, and that the mantle dorsal to it increases, especially on the umbilical wings. Throughout development, and also despite all the distortions associated with asymmetry (Pl. IV), the siphuncular cord and ventral lobe remain intimately related.

The close similarity in form between the early septum and the central part of the adult septum suggests that the study of the latter may give some clue to the development. In actual practice the contouring of a cleaned septum was found to be unsatisfactory for this purpose, inasmuch as the instrument could not be made to deal efficiently with undercut or even vertical portions of the surface. On the other hand, septal sections proved highly satisfactory. Before considering these, it will be necessary to provide a basis for comparison by giving an account of the suture-line of *Dactylioceras* and of its development.

VIII. The Adult Suture of the Dactyloidæ.

Before proceeding to the detailed description of the adult suture in the specimen from which both developmental details and septal sections were obtained, it will be helpful to refer briefly to the general features of the suture-lines in the family Dactyloidæ and in the Cœloceran forms from which it has been derived. Unfortunately, the material at our disposal was neither abundant enough nor sufficiently complete to permit the elucidation of major and minor lines of descent within these families. Nevertheless, there was sufficient to lead to the detection of certain tendencies which throw much light upon the problem now being considered.

The material examined included the following species :—

Dactylioceras commune (Sowerby).	*Peronoceras fibulatum* (J. de C. Sowerby).
D. crassum (Young & Bird).	*Porpoceras andræi* (Simpson).
D. annulatum (Sowerby).	*Cœloceras pettos* (Quenstedt).
D. turriculatum (Simpson).	*C. fonticulus* (Simpson).

The general relationships of some of the variations of the suture-lines within this family may be illustrated from one specimen of *Dactylioceras* by a comparison of its last suture with that of a slightly earlier one, namely, the tenth from the last (fig. 8, ii & iii).

During the interval between the deposition of these two septa

[1] *Op. cit.* p. 62.

some change—which, following the prevailing custom, may be ascribed to the onset of senile decay - had taken place in the animal. This expressed itself in the suture-line by a considerable decrease in the antero-posterior range of the lobes and saddles, accompanied by a swinging forward of the umbilical portion of the suture-line. These changes, which lead to a crumbling-down of the apices of the saddles to approximately the same plane, strongly suggest a diminution in the forward convexity of the septum. Meanwhile the saddles broadened out, and the demarcation from the lobes became more ill-defined. In minor details the later septum seems at first more intricately wrinkled, a feature which is still better exhibited in other specimens (fig. 8, i), some of which show these and other 'ageing' characters through a wide range of septa. This complexity is strongly suggestive of the wrinkling of a collapsing or flaccid bladder, as opposed to the simpler and more turgid outlines of the folioles in earlier septa, and suggests a diminution in the vigour of gas-secretion in the declining period of life.

Fig. 8.—*Suture-line of* Dactylioceras *and* Cœloceras.

[1–3 = *Dactylioceras commune*; 2, at the diameter of 45 mm.; 3, at the diameter of 39 mm. 10 sutures earlier in the same specimen. 4 = *Cœloceras fonticulus* from Whitby; diameter, 28 mm. 5 = *Cœloceras pettos* from Baden; diameter, 27 mm.]

The features that distinguish the earlier septum become more obvious in the primitive members of the family, and lead by an almost perfect gradation of changes to the condition observed in *Cœloceras pettos* (fig. 8, v).

The Dactyliocerates are evidently a decadent offshoot of *Cœloceras*.[1] In them are to be seen the phenomena which

[1] S. S. Buckman, 'On the Grouping of some Divisions of so-called "Jurassic" Time' Q. J. G. S. vol. liv (1898) p. 442.

characterize the first stages in the simplification of the suture-line, a simplification that is carried to such extremes in Cretaceous ammonites.

IX. The Adult Suture of *Dactylioceras commune*.

The adult suture (fig. 9 *i*, fig. 10 *m*) shows externally a deep ventral lobe divided by a median saddle, and flanked by broad external saddles. The first lateral lobes are almost as wide, but not so deep, as the ventral lobes; while the first lateral saddles are of smaller proportions than the external saddles, presenting in this respect a marked contrast with *Tragophylloceras*. The second lateral lobes are very small, and the two auxiliary saddles of the external series are insignificant. Internally, the dorsal lobe with its minute median saddle is the most important feature, being exceeded in depth only by the corresponding lobe of the external series. A pair of internal saddles, about as high but slightly narrower than the first lateral saddles, and a pair of smaller auxiliaries separated from the internal saddles by internal lobes, are also present. All the features of the suture-line, except the auxiliaries, are complicated by the presence of frillings or denticulations. On each of the external saddles are three main divisions similar to the simple divisions on the internal saddles. The first lateral lobe of the left [1] is markedly trifid. That of the right side is abnormal. A similar asymmetry has been noticed in other ammonites, as, for example, in *Sonninia*.[2] While these major frillings are symmetrically developed on each side of the median line, the minor frillings are less constant, and frequently give rise to asymmetry. Thus, although the three minor frillings on the central division of the external saddle are present on each side, the small frills on the dorsal foliole of the same saddle are much more developed on the left than on the right side. It appears, therefore, that, at least in such retrogressive types as *Dactylioceras*, only the major frillings can be of systematic importance. The minor frillings, which further complicate the suture, show even on opposite sides of the same suture an inconstancy that may be associated with the phenomena of decline discussed above.

X. Development of the Suture in *Dactylioceras*.

The first suture (fig. 9 *a*, p. 42) of *Dactylioceras* shows the usual angustisellate condition.

In the second suture (9 *b*) a well-defined ventral lobe is present, which is as broad as it is deep. The dorsal lobe is similar, but smaller; both are deeper than the lateral lobes. As in the adult suture, the external saddles are the largest, and the internal saddles come next in size. The first lateral saddle is just appearing as a low fold close to the umbilical angle.

[1] Right and left as used in the description refer only to the figures.
[2] S. S. Buckman, 'Inf. Ool. Ammonites' Monogr. Palæont. Soc. 1894, p. 381.

In the seventh suture (9 *c*) the same proportions are maintained. The new features to be noticed are the appearance of a median ventral saddle, the increase in size of the lateral saddle, and the presence of another saddle, the internal auxiliary, near the umbilical angle.

The folds just described persist throughout the remainder of the first three whorls, with little change in their relative proportions. Meanwhile crimping begins, and the first external auxiliary appears near the umbilical angle (9 *e*). The external saddle becomes trilobed, and thus resembles the internal saddle of the adult. The first lateral lobe on the left is trifid, while that of the right is only bifid; thus, even at this early stage, the curious asymmetry already noted in the adult has become established.

In the fourth whorl (9 *f*) frilling becomes still more marked.

In the fifth whorl (9 *g*) crimping is carried farther, but its small taxonomic value is made evident by a comparison of the right and left sides. The left lateral lobe is wide, and has the primitive five-fingered appearance of the corresponding lobe in *Cœloceras* (fig. 8, iv & v, p. 39). Up to this stage the outlines are all manifestly turgid.

In the sixth whorl (fig. 9 *h*, p. 42) conditions giving rise to flaccid outlines have begun to set in.

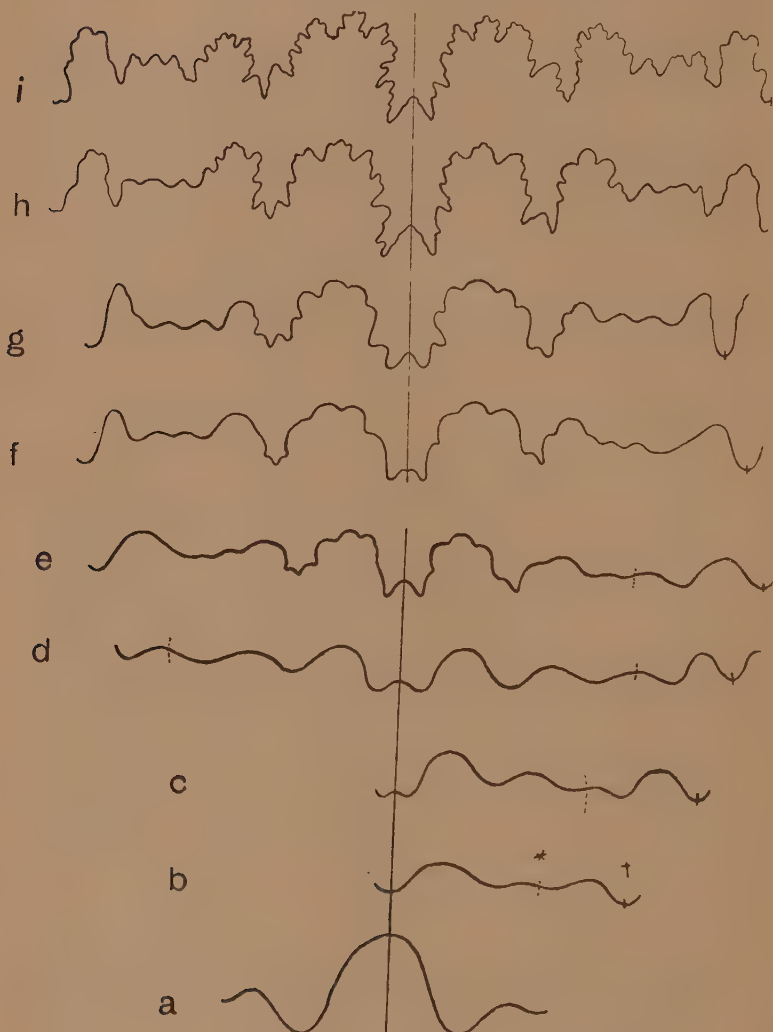
The development of the dorsal series of lobes and saddles proceeds along similar lines to that of the ventral series, but the details are later in appearing. For example, no signs of frilling are present on the lobes and saddles of the dorsum at the fourth whorl (9 *f*), yet marked frilling was already manifest in the ventral series before the end of the third whorl (9 *e*). Again, the median saddle of the dorsum does not appear until the fifth whorl, and it always remains small; but the corresponding saddle of the ventral series is present three whorls earlier. Further illustrations of the same principle are afforded by the development of *Tragophylloceras* and *Sphæroceras*. Branco noted a similar feature in many other ammonites. The conditions in *Clymenia* (Palæontographica, pt. 2, vol. xxvii, 1880, pl. viii) are exceptional, for the dorsal folds are more deeply divided than the ventral. The fact that in it the siphuncle is dorsal suggests that the complexity of folding is, in some way, associated with the position of the siphuncle.

XI. Septal Sections of *Dactylioceras*.

In the foregoing pages it has been shown that the central area of an adult septum is strikingly similar to the earlier septa. This fact suggests that, if septal sections were made, they would show some resemblance to the suture-lines at different stages in development.

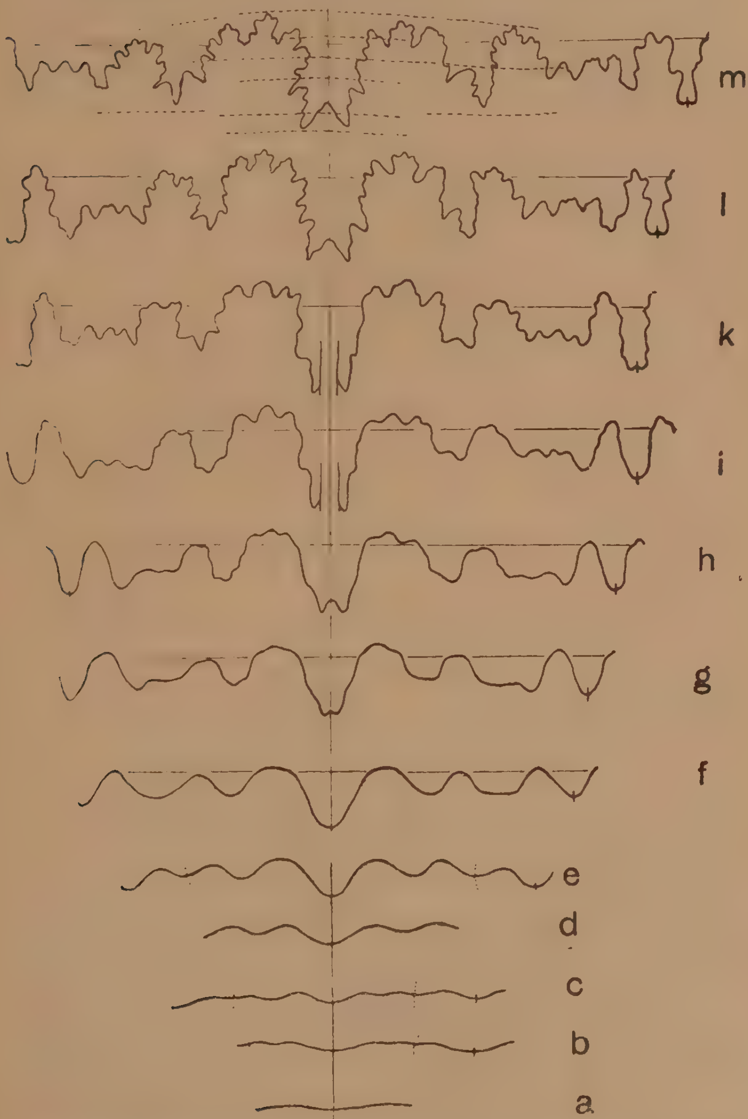
Fig. 10 (p. 43) shows a series of such sections made at the zonal lines shown in fig. 11. Thus section *b* represents the ground edge of the septum at zonal line 2 of fig. 11 (p. 44). This illustrates the extraordinary flatness of the innermost area of the septum.

Fig. 9.—*Development of the suture-line of* Dactylioceras commune (*figured in Pl. II, fig. 2*).



a = First suture × 28.
b = Second suture × 28.
c = Seventh suture × 28
d = Suture at $1\frac{3}{4}$ whorls × 28.
e = Suture at $2\frac{3}{4}$ whorls × 15.
f = Suture at $3\frac{3}{4}$ whorls × 12.
g = Suture at $4\frac{3}{4}$ whorls × 8.
h = Suture at $5\frac{3}{4}$ whorls × 4.
i = Suture at $6\frac{3}{4}$ whorls × 2.

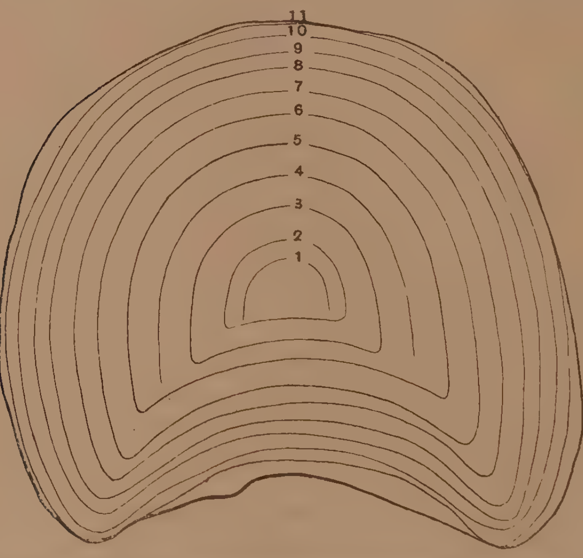
Fig. 10. *Series of septal sections made from one of the latest septa of the* Dactylioceras *figured in Pl. II. fig. 2.* ×2.



[The horizontal lines indicate the position of the datum-plane. The broken lines indicate the positions of the ribs on the original surface. The letters correspond with the numbers of fig. 11, p. 44.]

Passing outwards from this, the sections show ever more clearly defined indications of folding until at section *e* (fig. 10, p. 43) they are distinct enough to permit of comparison with the second suture (9 *b*, p. 42). Such comparison shows that, except for the flattening of the features, all essential characters of the latter are to be seen. If it were not for the enlargement of the first lateral saddle, the fifth septal section (fig. 10 *e*) would be identical with the second suture (fig. 9 *b*). This discrepancy is slightly rectified in the sixth section (fig. 10 *f*).

Fig. 11.—*Section of whorl* (× 6) *along the datum-plane of the septum whereof sections are shown in fig. 10, p. 43.*



[The lines parallel to the periphery show the positions of these sections. The numbers 1, 2, 3, etc. correspond to the letters *a*, *b*, *c*, etc. in fig. 10.]

The seventh section (10 *g*) is comparable with the seventh suture (9 *c*) and those which follow it as far as the second whorl (9 *d*), or even a little later. This is shown by the appearance of the internal auxiliary, and of faint indications of frilling on the external saddles and on the first lateral lobes. It should be noticed that at this stage, so far as main folds are concerned, the tendency to flattening has been reversed, and the features are now relatively deeper and narrower than in development. Section 8 (fig. 10 *h*) is comparable with the sutures in the third whorl (9 *e*), differences being similar to those noticed in the previous section: that is to say, the crimping, having just made its appearance, is (on the whole) flatter than in the corresponding developmental stage.

It is interesting to notice that the asymmetry due to the abnormal characters of the first lateral lobe of the right side is shown clearly in the septal sections as well as in the development of the sutures, a fact which emphasizes the soundness of the conclusion, to which this comparison seems to be leading, that the septal sections may be used for ascertaining some of the leading points in the development of the sutures.

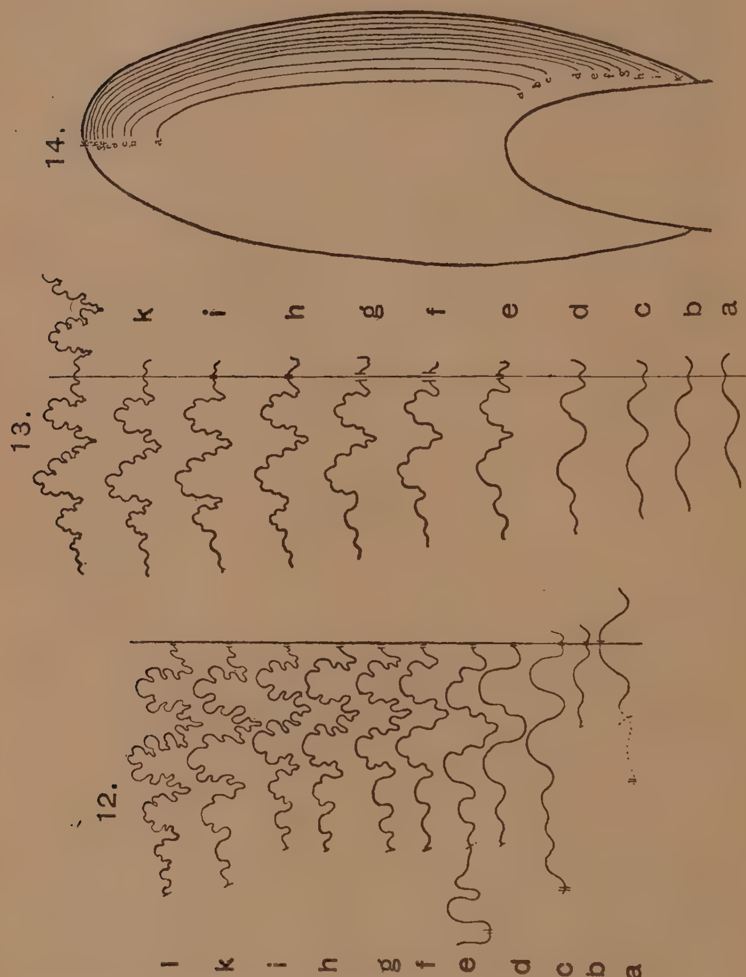
Septal section 9 (fig. 10 *i*) is comparable with the sutures of the fourth whorl (fig. 9 *f*) except that the second auxiliary has made its appearance, and that the frilling has changed in the same way as did the major folds of the earlier sections: that is to say, they have become deeper and narrower than in the corresponding sutures. Their relative proportions are the same: for example, in the sutures of the fourth whorl (9 *f*) the external saddles are asymmetrically subdivided. A similar asymmetry may be detected in the ninth section (10 *i*). The tenth section (10 *k*) also bears much detailed similarity to the sutures of the fifth whorl (9 *g*): observe, for example, the five-fingered appearance of the left lateral lobe. By this stage in development the animal has begun to assume adult characters.

XII. Septal Sections of *Tragophylloceras loscombi* (J. Sowerby).

The shape of the whorl of *Dactylioceras* does not depart greatly from that which is normal for ammonites. We have yet to examine to how great an extent the characteristic just observed in *Dactylioceras* is true for ammonites in which the whorl has become either compressed or depressed. As an example of a type with a compressed whorl, *Tragophylloceras loscombi* is here taken. The septal sections shown in fig. 13 (p. 46) are lettered for comparison with the stages in the sutural development (fig. 12). The positions of the sections in the whorl are indicated in fig. 14.

The specimen of this genus used by us was a young one. Its size and last suture show that it comes in between *k* and *l* of Mr. Spath's series (*op. cit.* 1914, p. 340; see fig. 12). It shows differences from his specimens, which must be borne in mind when comparing septal sections made from it with the developmental series given by him. For example, the great size of the terminal leaflets of the external and first lateral saddles shown in his sutures at *k* and *l* does not appear in the last suture of our specimen. This fact may account for the relative smallness of those leaflets in the septal sections. Again, Spath's figures of sutures *h* and *i* do not form a continuous series with *g* and *k*: compare, for example, the second lateral saddle and also the terminal leaflets of the external saddles. We have been unable to detect this break in the earlier sutures of our specimen, so that its absence in the septal sections can hardly be accepted as evidence against their value.

Figs. 12–14.—Tragophylloceras loscombi *(J. Sowerby)* *from Lyme Regis.*



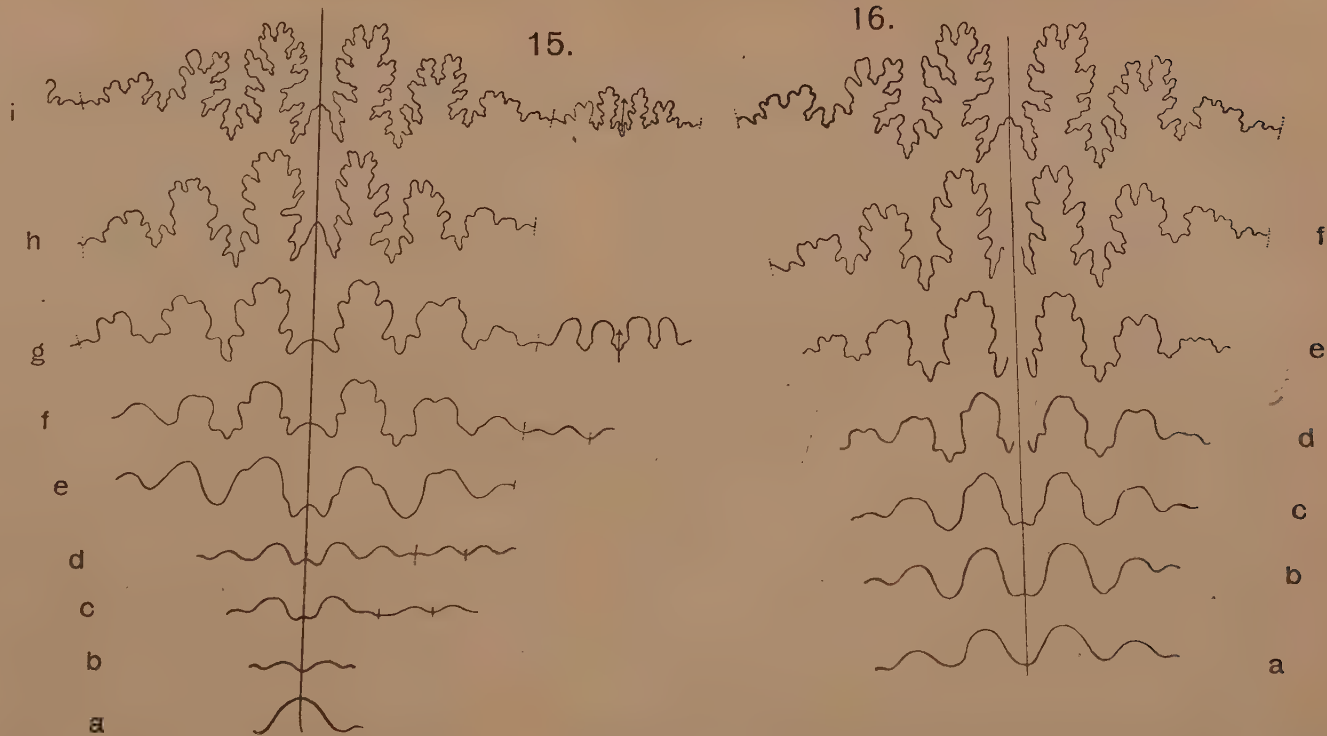
[12 = Development of suture (from L. F. Spath, *op. cit.* p. 341); 13 = Series of septal sections made from one septum, × 2; 14 = Section of the whorl along the datum-plane of that septum, showing the positions of these septal sections.]

As in *Dactylioceras*, the smaller details of the suture are so asymmetrical about the median line as to indicate that they are of little consequence in taxonomic discussion. Here, again, the comparison of the developmental series and the septal sections may be confined to the more outstanding features. The sections give nothing comparable with the first suture, but the innermost sections (fig. 13 *b* & *c*) are almost identical with the seventh suture (fig. 12 *c*). This similarity is emphasized by the presence of the ventral saddle which, by acceleration in development, appears earlier in development in *Tragophylloceras* than in *Dactylioceras*: a difference in the time of appearance which is manifested also by the sections of the two types. As in *Dactylioceras*, the fresh lobes and saddles appear at the umbilical angle in both sutures and sections. In the sutures, the first denticulation is shown on the external saddle, new frillings coming in rapidly from that time onwards. Although the relative proportions of these divisions are not the same in the sections as in the sutures, the numbers at the various stages are practically identical. The difference in proportions may be partly explained by the difference between Mr. Spath's specimen and ours, as mentioned previously. It may also be suggested that the notches which produce 'undercuts' on the folds are confined to the edge of the septum, and are therefore necessarily shown only in the sutures, yet are absent from the inner portions of the early as well as the latest septa. This last fact is of practical value in breaking up an ammonite for examination: for, if the outer surface is filed away along any suture-line, the chambers may be readily separated.

XIII. Septal Sections of *Sphæroceras brongniarti* (J. Sowerby). (See figs. 15 & 16, p. 48.)

The septal sections of this specimen correspond very closely with the developmental series. The order of appearance of denticulations in ontogeny is closely paralleled in the sections. Thus the first frillings in each series are developed in similar positions on the external saddles (compare fig. 16 *c* & *d* with fig. 15 *c*) after the appearance of the median saddle in the ventral lobe. At this stage there are three pairs of saddles in both cases. The development of additional frillings and of small auxiliaries also proceeds along almost identical lines. It will be noted, however, that in ontogeny the median ventral saddle is present at an earlier stage than in the sections: namely, before the development of the second lateral saddle. The differences noted in the previous comparisons are also to be seen here; the undercuts, which are well developed in ontogeny, are only preserved in the outer parts of the septum, and consequently do not appear in any but the outermost sections. Further, even in the inner septal sections, main folds are generally more acute than in development. This is due to the absence of a central flattened area.

Figs. 15 & 16.—Sphæroceras brongniarti *(J. Sowerby) from Sherborne.* *Diameter=16 millimetres.*



15.—Development of the suture. *a*= First suture ×25. *b*= Second suture ×25. *c*= Third suture ×25. *d*=Suture at the diam. of 1·5 mm. ×12. *e*=Suture at the diam. of 2·2 mm. × 12. *f*=Suture at the diam. of 2·3 mm. × 9. *g*= Suture at the diam. of 4 mm. × 9. *h*=Suture at the diam. of 8 mm. × 7. *i*=Suture at the diam. of 16 mm. × 4.

16.—Series of septal sections made from one septum. × 2½.

Nevertheless, the similarity is sufficiently striking to justify the opinion that the principle educed from the septa of normally-shaped and compressed whorls holds good also, with the limitations noticed, for forms with depressed whorls.

Fig. 17. *Section of the whorl of* Sphæroceras brongniarti *along the datum-plane of the septum of which septal sections are shown in fig. 16* *(p. 48)*. *The lines parallel to the periphery show the positions of these sections.*

XIV. The General Consideration of Septal Sections.

Mr. R. T. Jackson[1] has drawn attention to the phenomenon of localized stages in development: that is to say, during life

'stages may be found in localized parts which are similar to stages found in the young, and the equivalents of which are to be sought in adults of ancestral groups.'

Thus, for example, the auxiliary saddles in the suture of *Tragophylloceras* are similar to the external and lateral saddles of the first suture. The idea has been applied to the study of different species in a progressive series (*Lytoceras*) by Mr. S. S. Buckman,[2] who has shown that the first lateral saddle of an early type is at the same stage as the second lateral of a more advanced type.

The similarity of the central area of the adult septum to the earlier septa is not, however, an illustration of the same principle. All Jackson's illustrations are drawn from newly developed parts,

[1] 'Localized Stages in Development in Plants & Animals' Mem. Boston Soc. Nat. Hist. vol. v (1899) p. 92.

[2] 'On certain Genera & Species of Lytoceratidæ' Q. J. G. S. vol. lxi (1905) p. 151.

such as the auxiliaries of suture-lines, the last-formed plates in the stalk of a crinoid, or in the interambulacral area of an echinoid. The simplicity of the central area of the adult septum is due to the retention of this feature through all stages of development, despite the increasing complexity of adjoining parts.

Just as the development summarizes the stages of evolution with omissions here and additions there, so septal sections summarize the development, but with omissions only. The features to be omitted are determined by the fact that the series of changes, shown in the passage from the centre of the septum to the edge, represents the most direct way in which the adult septum, with its highly complicated margin, could have been evolved from a septum as simple as that of an asellate protoconch. If this course of evolution has been, as it were, a winding one, the winds will be omitted, to some extent in development, and completely in the adult septal sections.

In ammonites with normally-shaped whorls the septal sections closely resemble the sutural development: in highly-compressed and depressed forms, however, the central area of the septum is like a primitive septum greatly elevated or laterally extended. During ontogeny, the first lateral saddles in these forms early assume adult proportions, and consequently in septal sections the stages represented by the earliest sutures are omitted. In no case do septal sections show a stage comparable with the first suture. This seems to indicate that, in ammonites, a change akin to a metamorphosis took place in the period between the formation of the first and the second septum. The creature which secreted the former was possibly larval, and followed a line of evolution of its own: which is reflected in the series of cœnogenetic changes represented by the terms a s e l l a t e, l a t i s e l l a t e, and a n g u s t i s e l l a t e. Further, in such forms as *Pinacoceras*, where a large number of adventitious inflections are developed, and compression has reached its maximum, we should not expect to find so close an agreement between the septal sections and the sutural development.

With these exceptions, however, septal sections will at least furnish a standard of direct development,[1] which may be useful for detecting deviations in the normal development where such occur. This direct development may or may not approach as closely as ontogeny to a true representation of actual evolution.

Septal sections should prove especially useful where material for the study of early stages is not accessible. Although, in ordinary cases, sutural development may prove of greater value than the septal sections, where the former cannot be worked out the latter will, to some extent, serve as a substitute.

It is well known that the sutures of senile stocks bear a close resemblance to the young sutures of the advancing types which preceded them. This resemblance is due, not to a resumption of

[1] We owe this suggestion to a conversation with that brilliant and much lamented investigator, the late Dr. A. Vaughan.

embryonic characters which have disappeared as the study of the suture-lines alone seems to suggest, but to a bringing to the surface once more of those embryonic features which, even in acmic radicals, have persisted into adult life hidden from view by a narrow fringe of complicated frilling. During retrogression this fringe is gradually lost, and thus a process analogous to the making of septal sections takes place. Strictly, the sutures of senile stocks should be compared, not with those seen in the ontogeny of ancestral types, but with the septal sections of the ancestral adult septum. It is not at all unlikely that, while ontogeny summarizes progressive evolution, septal sections forecast in similar broad outlines retrogressive evolution. Thus, for example, a careful study of a large number of *Baculites*, and a comparison with the septal sections of ammonites from which they have probably descended, would make it possible to connect up with certainty many of these forms. It is to be regretted that inability to secure sufficient material has made it impossible for us to establish this principle satisfactorily.

XV. Asymmetry in Suture-Lines.

A marked tendency to asymmetry in suture-lines has already been noted in *Dactylioceras commune*. It is now proposed to deal with this aspect of the morphology of the septum more fully. Such asymmetry usually arises in one of two ways, namely :—

(1) By the different development of elements of opposite sides.
(2) By association with lateral displacement of the siphuncle.

The former is of common occurrence. It has already been described above for *Dactylioceras* (p. 40). It has been observed by S. S. Buckman in *Sonninia*[1] and by Solger in *Neoptychites*.[2] In each of these cases the first lateral lobes of opposite sides were different in plan. Other cases have been seen in which this character has been associated with a tendency to helicoid coiling, as in the '*Turrilites*' of d'Orbigny.[3] As O. Fraas has shown,[4] it is only when this character has become constant, as in *Turrilites*, that it is of generic importance.

Asymmetry associated with the displacement of the siphuncle may be brought about in various ways. The most instructive example that has come under our notice is that of a specimen of *Perisphinctes triplicatus*, found in the Kimeridge Clay of Market Rasen by Mr. F. T. Ingham. This specimen shows three septa (Pl. IV, fig. 2); the suture of the earliest is normal, that of the second is slightly irregular, that of the third is markedly distorted, for the siphuncle has during this short interval become

[1] 'Inf. Ool. Ammonites' Monogr. Palæont. Soc. 1894, p. 381.
[2] 'Die Fossilien der Mungokreide in Kamerun & ihre Geologische Bedeutung' Beitr. Geol. von Kamerun (1904) p. 107.
[3] 'Paléontologie Française: Terrains Crétacés' vol. i (1840) p. 571.
[4] 'Abnormitäten bei Ammoniten' Jahreshefte Württemb. xix (1863) p. 112.

considerably displaced from the median line. These features of the suture-line are only an external manifestation of an enlargement of one half of the septum (fig. 1) at the expense of the other; in such a manner that the internal as well as the external lobe has been pushed to one side, and the enlarged half has also been pushed behind the general level of the septum. That the asymmetry is not due to an injury seems probable, since it developed slowly enough to permit of the secretion of at least two septa. Neither does it appear to have been due to a change of the conditions which directly affect the form of the suture, since all the details are preserved. The cause was possibly pathological. The facts already discussed show that the form of the septum, even in these asymmetric examples, is independent of the internal organs in the neighbourhood of the septum: otherwise a diseased condition of some paired organs (for instance, the gonad) might have been postulated. As it is, the cause must be looked for in a diseased condition of the stretched membrane: namely, the septum-secreting area of the mantle. If this became hypertrophied on one side, it would still assume the form of a stretched membrane, but being more resistant to pressure from behind, would not become so concave forwards as the other half. This is precisely the condition which the shape of the abnormal septum suggests.

Usually the change in the position of the siphuncle takes place slowly and in one direction only; but in a specimen of *Hoplites auritus* (Pl. IV, fig. 8) it moves from side to side repeatedly, in association with the alternate development of tubercles on opposite sides of the venter. The mantle apparently sank into the cavities of the tubercles, and thus caused a displacement of the adjoining parts of the body as well as of the mantle.

Lateral displacement of the siphuncle in the example of *Perisphinctes* which we have just described has been accompanied by wholesale enlargement of one half of the septum, but usually only the ventral features of the suture are affected. Thus in the septum of *Hoplites splendens* (Pl. IV, fig. 4) all the elements of the internal series and those of the external series which are dorsal to the first lateral lobe, are quite normal. Further, in the septum of *Psiloceras planorbis* (Pl. IV, fig. 9), the displacement is of a character similar to that observed in *Hoplites splendens*: for there also the dorsal suture is not affected, while the elements of the venter are disturbed even more markedly than in the latter form.

Thus the displacement of the siphuncle in *Perisphinctes* and *Hoplites auritus* is different in origin from that of *Psiloceras* and *Hoplites splendens*. Dr. J. F. Pompeckj[1] has, for example, stated that the type of asymmetry in *Psiloceras* is of systematic value. The discovery, also by him, of a specimen of *Tragophylloceras* with a similarly asymmetric suture-line, has been mentioned

[1] 'Beiträge zu einer Revision der Ammoniten des Schwäbischen Jura' pt. i (1894) pp. 56–71.

by Spath (*op. cit.* 1914, p. 351), presumably as corroborative evidence of the connexions between *Psiloceras* and *Tragophylloceras*.[1] Similarly, this character has been described in *Cosmoceras* by Teisseyre.[2] Sayn[3] mentioned that he had not observed a similar feature in *Hoplites*, and considered that this showed conclusively that *Hoplites* was not directly descended from *Cosmoceras*. It should be mentioned, however, that A. d'Orbigny (1840, p. 222) had previously noticed that asymmetry is of common occurrence in certain species of *Hoplites* an observation which we are able to confirm.

An examination of sixteen specimens of *Psiloceras planorbis* from the Lower Lias of Robin Hood's Bay revealed asymmetry in nine cases. Although asymmetry is of common occurrence in *Psiloceras*, it would appear to be an unreliable character. Further, Pompeckj's figures show that the displacement varies in amount and direction.

The careful examination of the suture-lines of more than 600 Jurassic and Cretaceous ammonites has shown that asymmetry due to a displacement of the siphuncle occurs sporadically in many widely-separated genera. We have noticed it in the following cases:—

Psiloceras planorbis (Sowerby). [4]N.U.C., N.M. Robin Hood's Bay. 9 out of 16. Pl. IV, fig. 9.
'*Normannites*' *braikenridgi* (Sowerby). N.M. Mesvil (Yorkshire). 1 out of 2. Pl. IV, fig. 13.
Keplerites calloviensis (d'Orbigny). N.U.C., N.M. Ashton Keynes. 1 out of 3.
Aspidoceras perarmatum (Sowerby). N.U.C., N.M. Faringdon. 2 out of 4.
Hoplites splendens (d'Orbigny). N.U.C., N.M., B. Folkestone; Cambridge. 62 out of 112.
Hoplites raulinianus (d'Orbigny). N.M. Folkestone. 1 out of 2.
Dactylioceras commune (Sowerby). N.U.C., N.M., B. Whitby, etc. 10 out of 30.
Cosmoceras jason (Reinecke). N.U.C., N.M. Woburn Sands. 5 out of 12.

The occurrence of asymmetry in so large a number of examples of *Hoplites* is noteworthy, and fully bears out d'Orbigny's observation. Yet it should be mentioned here that, in 78 specimens of *Hoplites lautus* and *H. tuberculatus*, we were unable to detect

[1] Mr. Spath remarked that he had not observed any cases of asymmetry in the specimens of *Tragophylloceras loscombi* from Lyme Regis. Mr. W. D. Varney, however, has found an example of this species showing asymmetry at Old Dalby (North Leicestershire).

[2] 'Ein Beitrag zur Kenntniss der Cephalopoden Fauna der Ornatenthone im Gouvernement Rjäsan (Russland)' Sitz. Math.-Naturw. Classe, K. Akad. Wissensch. Wien, vol. lxxxviii, pt. 1 (1883) pp. 538–69.

[3] 'Ammonites Pyriteuses des Marnes Valangiennes du S.E. de la France' Mém. Soc. Géol. France, Paléont. vol. xv (1907) p. 65.

[4] N.U.C. = Teaching Collection, University College, Nottingham; N.M. = Natural History Museum, Nottingham; B. = Teaching Collection, Birmingham University.

one case of asymmetry. Further, asymmetry of a similar character has been observed by previous writers in a large number of other forms :—

Ammonites miserabilis Quenstedt (*Agassiceras* Hyatt).[1]
Ammonites falcaries Quenstedt.[1]
Oxynoticeras heteropleurum Neumayr & Uhlig.[2]
Hoplites oxygonius Neumayr & Uhlig.[2]
Engonoceras pierdenale var. *commune* Hyatt.[3]
Engonoceras uddeni Cragin.[3]
Oxynoticeras guibali Hyatt ('Genesis of the Arietidæ' 1889, p. 219 & pl. x, fig. 28).
Cosmoceras jason (d'Orbigny).[4]
Cosmoceras m. f. *jason* Reinecke, *C. proniæ* Teisseyre,[4] *C. pollux* Reinecke, *C. subnodatum*, *C. jenseni* Teisseyre (*op. cit.* 1884, pp. 538–69).
Ammonites convolutus Schl. (Fraas, *op. cit.* 1863, p. 111).
Ammonites denarius, *fittoni*, *lyelli* Leymerie.[5]
Ammonites coregonensis Sowerby, *Wæhneroceras guidoni* (Sowerby).[6]
Ammonites suessi, *A. abnormalis*, von Hauer.[7]

It will be noted that the greater number of the fossils in which this type of asymmetry has been observed are included in, or connected with, the families Cosmoceratidæ, Ægoceratidæ, and Stephanoceratidæ (according to the classification adopted by J. P. Smith).[8] Thus it would at first appear that the feature is of considerable systematic importance; yet it should be remembered that, although asymmetry is typical of certain species of *Hoplites*, in other species of the same genus we have not observed it. The presence or absence of examples of asymmetry, therefore, must not be taken as conclusive evidence of relationship in the face of other facts.

An examination of the lists just given shows that nearly every specimen in which this type of asymmetry has been observed has a rounded or flat venter. Although at least a third of the specimens examined had keeled venters, not one case of asymmetry has been detected by us among them. It would thus appear that the displacement is to a large extent associated with the shape of the whorl. Nevertheless, asymmetry may occur occasionally in

[1] F. A. Quenstedt, 'Die Ammoniten des Schwäbischen Jura' Stuttgart, 1885, pl. xiii, figs. 15, 29.

[2] M. Neumayr & V. Uhlig 'Ueber Ammoniten aus den Hilsbildungen Norddeutschlands.' Palæontographica, vol. xxvii (1880–81) pp. 135, 171.

[3] A. Hyatt, 'Pseudoceratites of the Cretaceous' U.S. Geol. Surv. Monogr. xliv (1903) pp. 159, 165.

[4] A. d'Orbigny, 'Paléontologie Française: Terrains Oolitiques ou Jurassiques' vol. i (1842) p. 448.

[5] M. Neumayr & V. Uhlig, Palæontographica, vol. xxvii (1880–81) pp. 219–55.

[6] P. Savi & G. Meneghini, 'Osservazioni stratigrafiche & paleontologiche concernenti la Geologia della Toscana' 1851, pp. 73–77.

[7] F. R. von Hauer, 'Ueber einige unsymmetrische Ammoniten aus den Hierlatzschichten' Sitz. Math.-Naturw. Classe, K. Akad. Wissensch. Wien, vol. xiii (1854) pp. 401–410.

[8] Cephalopoda, in K. von Zittel's 'Text-book of Palæontology' (transl. Eastman), 2nd ed. (1913) p. 150.

some keeled forms; for it has been recorded in *Ammonites miserabilis* Quenstedt, in *Oxynoticeras heteropleurum*, and in *O. guibali*. In the latter genus, at all events, the exception is only apparent, for the venter may be strictly considered as rounded, on account of the hollow keel.[1]

Asymmetry has been observed in *Hoplites tuberculatus* by G. C. Crick,[2] but here it was accompanied by a distortion of the shell; yet a specimen with asymmetric ornament may have a normal suture, as seen in an example of *Ammonites amaltheus*.[3]

The asymmetry which occurs so commonly in *Hoplites splendens* and *H. raulinianus* is usually accompanied by the displacement of the siphuncle into the angle bounding the flat venter. At 12 mm. diameter in each of the specimens the sutures were symmetrical, and at this stage the specimens had round venters (Pl. IV, fig. 5 *a*). From this stage until a whorl later (Pl. IV, fig. 5 *b*) the siphuncle became gradually more displaced; but only the ventral part of the septum became distorted, for all the features dorsal to the first lateral lobe remained normal. Similar characters were observed by A. d'Orbigny[4] in the development of asymmetry in *Ammonites denarius*. Asymmetry in these cases is probably a growth phenomenon, associated with the tendency of the siphuncle to take up a stable position along the angle bounding the venter.

Accompanying the displacement there has been in many forms a rapid change in the form of the suture, which is probably a result of the increased area on that side of the siphuncle. It illustrates the manner in which the form of a suture may be changed owing to a rapidly increased height of whorl. Thus in *Hoplites splendens* (Pl. IV, figs. 4–6) the external saddle at first has two main divisions; but later it becomes trilobed. Further, in *Cosmoceras* (Pl. IV, fig. 10) the external saddle of the enlarged side is practically double the breadth of the corresponding saddle of the other side. In association with this increase in relative size the saddle has become more deeply denticulated, and the major frillings have become indented by numerous minor frills which are but feebly represented on the other side. This peculiarity has been studied in some detail by Teisseyre.[5]

He suggested that the displacement that we have described is a growth-phenomenon associated with the form of the whorl. Solger[6] believed that the movement of the siphuncle away from the median plane was due to the adoption of a recumbent habit.

[1] A. Hyatt, Smithsonian Contributions to Knowledge, No. 673 (1889) pl. x, fig. 28.

[2] 'A deformed example of *Hoplites tuberculatum*,' Geol. Mag. dec. 4, vol. v (1898) p. 541.

[3] O. Fraas, Jahreshefte Württemberg. xix, 1863, p. 111.

[4] A. d'Orbigny, 'Paléontologie Francaise: Terrains Crétacés' vol. i (1840) p. 222.

[5] L. Teisseyre, Sitz. Math.-Naturw. Classe, K. Akad. Wissensch. Wien, vol. lxxxviii, pt. 1 (1883) pp. 604–608.

[6] F. Solger, 'Beiträge zur Geologie von Kamerun,' 1904.

Dr. O. Abel[1] considers that, while many ammonites were adapted for a swimming life, yet many of the 'one-sided' forms that we have mentioned had a benthic habit. He also suggested that the presence of a keel in a nectonic animal would assist rapid motion. As we have seen, asymmetric siphuncles rarely occur among these keeled forms, which presumably had rarely a benthic habit.

Briefly then, although a displaced siphuncle and an asymmetric suture may be most usually developed in certain connected species, the existence of such abnormalities in a single specimen is not sound evidence of genetic affinity.

In conclusion, we wish to express our thanks to those who have helped us: to W. D. Lang, M.A., F.G.S., for gifts of material; to Prof. J. W. Carr, M.A., F.G.S., for permission to examine the collection in the Nottingham Museum; and to Prof. W. S. Boulton, F.G.S., for allowing us similar access to the collection in the Birmingham University.

EXPLANATION OF PLATES II–IV.

Plate II.

Fig. 1. Apparatus used in surveying and levelling the surfaces of septa and of whorls.

2. *Dactylioceras commune* (J. Sowerby), from Whitby. Specimen used for working out the development of the septum, the suture-line, and for making septal sections. Diameter = 7·5 cm. $\times \frac{2}{3}$.

3. Portion of the whorl of another specimen of the same species filed away in steps, in order to show septal sections of successive septa. $\times 1\frac{1}{2}$.

4. Series of septal sections drawn from this specimen.

Plate III.

Figs. 1–5. Development of the septum of *Dactylioceras commune*. Figs. 2–5 are from the specimen shown in Pl. II, fig. 2.

Fig. 1. Adult septum. $\times$ 4·5. (Text-fig. 4.)

2. Septum at $2\frac{3}{4}$ whorls. $\times$ 22.
3. Do. at $2\frac{1}{4}$ whorls. $\times$ 25.
4. Do. at $1\frac{3}{4}$ whorls. $\times$ 35. } The numbering of figs. 4
5. Second septum. $\times$ 40. (Text-fig. 6, p. 36.) } & 5 should be reversed.
6. Almost adult septum of *Tragophylloceras loscombi* (J. Sowerby), from Lyme Regis. Diameter = 17 mm. $\times$ 6.
7. Adult septum of *Sphæroceras brongniarti* (J. Sowerby), from Sherborne. Diameter = 20 mm. $\times 2\frac{1}{2}$.

Plate IV.

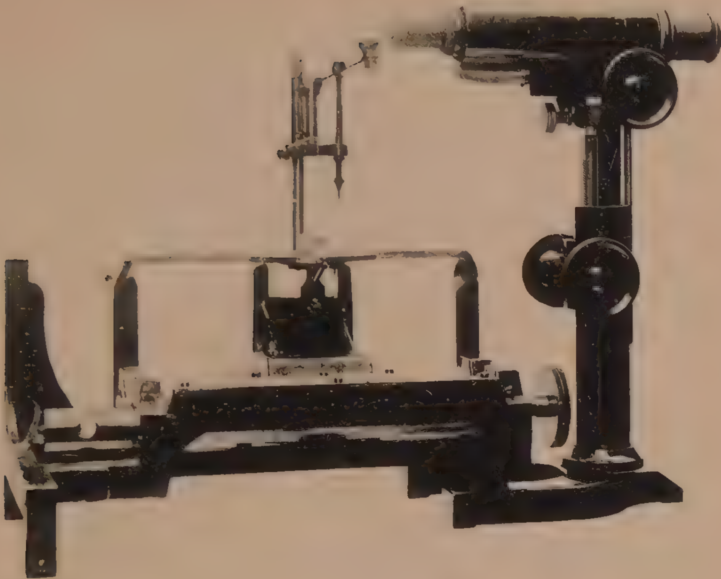
Figs. 1–3. *Perisphinctes triplicatus*, from Market Rasen.

Fig. 1. Front view of an abnormal septum. Natural size.

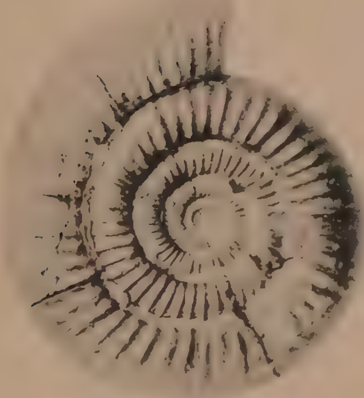
2. Ventral view of a portion of an outer whorl. Natural size.
3. Last suture shown by this specimen.

[1] 'Verbreitung & Lebensweise der Ammoniten' Verhandl. k.-k. Zool.-Botan. Gesellsch. Wien, 1912, p. 83.

1.



2.



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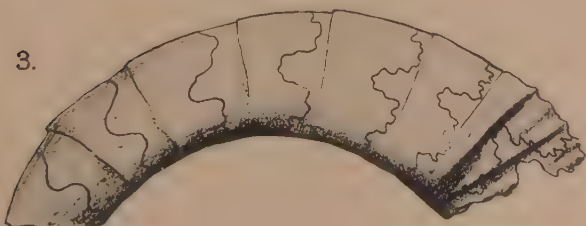
3.

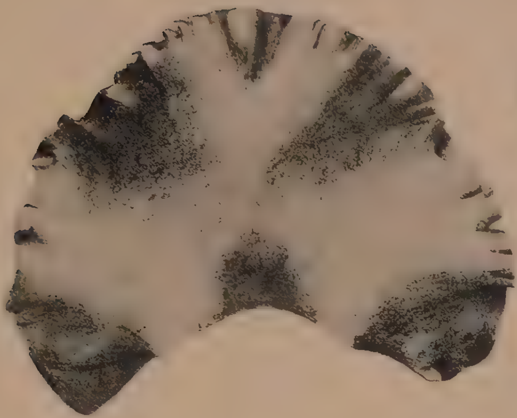


A.E.T., del.

Bemrose, Collo., Derby

DEVELOPMENT OF THE AMMONITE SEPTUM.

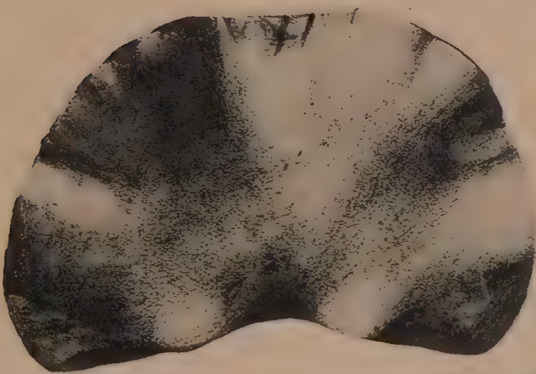
1.



4.

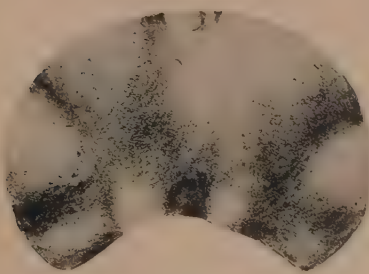
5.

2.



6.

3.

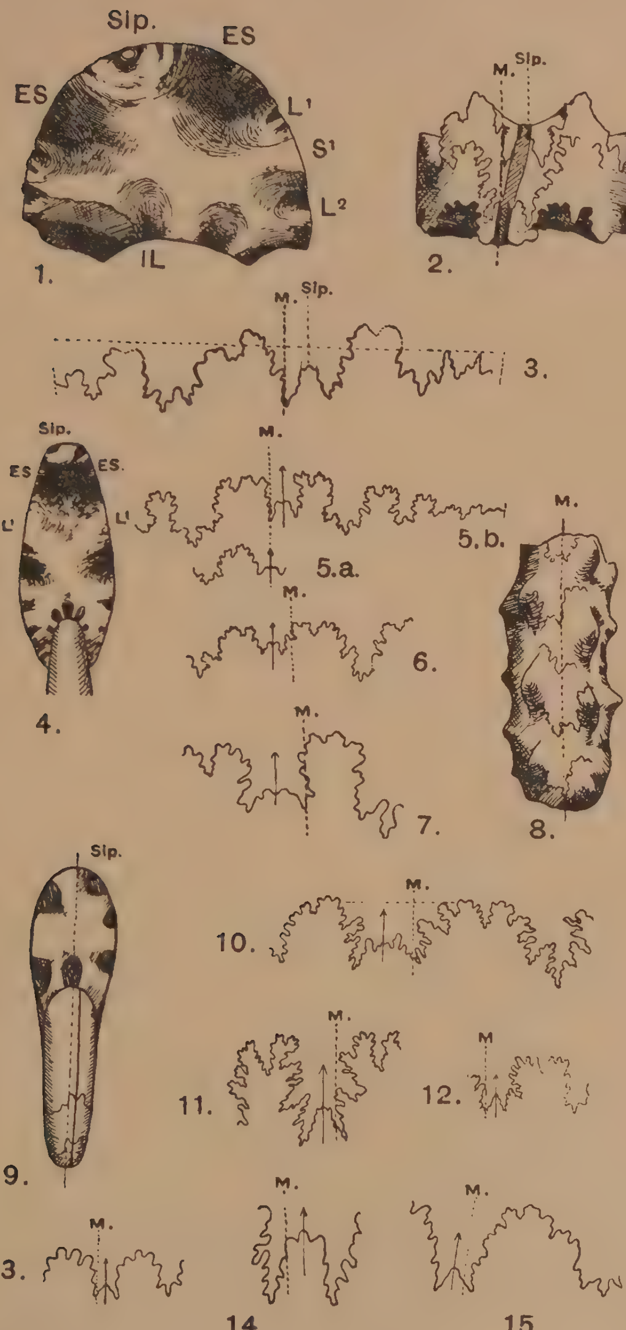


7.

A.E.T., del.

Bemrose, Collo., Derby.

DEVELOPMENT OF THE SEPTUM OF DACTYLIOCERAS COMMUNE, ETC.



A.E.T., Del.

DEVELOPMENT OF THE AMMONITE SEPTUM.

Figs. 4–6. *Hoplites splendens.* Diameter = 34 mm.

Fig. 4. Septum showing displaced siphuncle, and distortion associated therewith.

5 *a*. Suture of the same at 12 mm.

5 *b*. Do. do. at 32 mm.

6. Do. of another specimen.

7. *Hoplites raulinianus.* Folkestone. Suture.

8. *Hoplites auritus.* Cambridge. View of venter showing displacement of the siphuncle, first to one side and then to the other.

9. *Psiloceras planorbis.* Robin Hood's Bay. Showing position of displaced siphuncle.

Figs. 10–15. Asymmetrical sutures of various ammonites.

Fig. 10. *Cosmoceras jason.* Buckinghamshire.

11. '*Normannites*' *braikenridgii.* Mesvil.

12. *Aspidoceras perarmatum.* Faringdon.

13. *Uptonia jamesoni.*

14. *Keplerites calloviensis.* Ashton Keynes.

15. *Dactylioceras commune.* Whitby.

IL = Internal lobe. ES = External saddle. L^1 = Principal or first lateral lobe. L^2 = Auxiliary lobe. S^1 = First lateral saddle. M = Median plane. Sip. = Siphuncle.

Discussion.

Dr. F. A. Bather thanked Prof. Swinnerton for his well-illustrated and lucid exposition. It had been said that in science the invention of a new method was worth more than the discovery of a hundred facts. The instrument devised by the Authors might be applied to the reproduction of other complicated surfaces. The ammonites illustrated had all been progressive types, and apparently the method was unsuitable when retrogression had set in. In progressive types the study of a late-formed septum enabled one to work backwards, but not forwards, to the unknown. Might it not, however, be possible to forecast the lines of retrogression? In any case, the method would facilitate the determination of affinities and the plotting-out of definite series on which more secure inferences could be based.

Dr. A. M. Davies said that the suggestion that septal sections might be used as a means of studying the development of the septum had been made to him in conversation by Mr. S. S. Buckman some years ago. He congratulated the Authors on their success in demonstrating the truth of this suggestion. He enquired as to how far coarse ornamentation would interfere with the application of the method, and whether it was really trustworthy in the case of septa which had undergone catagenetic simplification.

Prof. H. H. Swinnerton thanked those present for the kind reception given to the paper. Replying to Dr. Bather, he stated that 'septal sections' supplied a standard of the most direct line of development leading up to the condition found in the particular septum from which they had been made; for that reason they would not record any deviations from that line occurring during evolution or development. The study of the septal sections of a simple

septum could not be expected to throw light upon the possible complications which might arise in the future in a progressive series. On the other hand, sections of a complicated septum such as that of *Lytoceras* might reasonably be expected to show resemblances to the sutures of any species of *Baculites* of Lytoceratan origin. Replying to Dr. Davies, he expressed the opinion that the presence of coarse ornamentation on the surface of an ammonite would not seriously impair the usefulness of septal sections. The resemblance of the inner part of the septum to the early septa was not really an example of the phenomenon defined in the phrase 'localized stages in development.'

4. SUPPLEMENTARY NOTES *on* *ACLISINA* DE KONINCK *and* *ACLISOIDES* DONALD, *with* DESCRIPTIONS *of* NEW SPECIES. By JANE LONGSTAFF (*née* DONALD), F.L.S. (Communicated by Dr. G. B. LONGSTAFF, M.A., F.G.S. Read May 2nd, 1917.)

[PLATES V & VI.]

IN 1898 I communicated a paper to this Society on the genus *Aclisina* and on *Aclisoides*, a new section or subgenus of *Murchisonia*. Since that date I have had the opportunity of studying a larger number of specimens, which has not only enabled me to learn more about the species then described, but also to add to their number.

Fifteen species of *Aclisina* with several varieties, and a single species of *Aclisoides* with one variety, were dealt with in 1898. I am now referring seven more species to the former, six of which have not been previously noted, and am regarding the form considered a variety of the latter as a distinct species. Thus we have a total of twenty-two possible species of *Aclisina* and two of *Aclisoides*. In addition to these there are in the Sedgwick Museum, Cambridge, three small shells resembling *Aclisina*, one from Poolvash, the others from Settle, all too much embedded in the matrix to be accurately determined.

The numbers given can only be regarded as approximate, for paucity of specimens and defects in the manner of preservation sometimes render the definition of genera and species difficult. It is, therefore, possible that some shells at present considered as distinct species may afterwards prove to be varieties only, while others now grouped together may need to be separated.

In the previous paper no holotypes were selected. I am now supplying the omission, and also stating in which collections they are deposited.

Although I have already remarked on the beautiful state of preservation of many of the Scottish specimens, it may not be amiss to draw attention to it again. No less than thirteen species of *Aclisina* and one of *Aclisoides* have the protoconch well preserved. In the latter it is attached to the post-embryonic whorl and simply coiled on the same plane, and thus in no wise peculiar. But in *Aclisina* it is markedly so, being more or less irregular. In six species the protoconch stands up, forming a wide angle with the post-embryonic whorl; in four it is not so much raised, but is oblique and overhangs the spire; in the remaining three it is wholly attached, forming a broad flat apex.

The material at hand is not sufficient to show to how great an extent variation in the character of the protoconch of a species may take place, either in the same beds, or in those separated by time or

space. In no instance have I observed a species including individuals with the protoconch greatly elevated and others with it flat. In two species, *Aclisina micula* and *A. striatissima*, I have noted very slight variation. Only two examples of the former are known to me: in one the protoconch adheres closely, in the other it is a little raised, and in one example of *A. striatissima* (Pl. VI, fig. 4) it is flatter than in the type. In some shells one or more of the upper whorls of the spire are unattached, as well as the protoconch: as, for instance, *A. aciculata* (Pl. VI, fig. 6). The protoconch is frequently more translucent than, or of a different colour from, the rest of the shell.

I have previously noted that the Scottish Gasteropoda as a whole are small. There are, however, exceptions to this, for at Craigenglen and Strathavon, both near the base of the Lower Limestone Series, larger shells occur, equalling in dimensions individuals of the same species at Settle and Visé. Mr. Peter Macnair suggests that this may be the result of the clear-water conditions which prevailed during the deposition of the beds at these localities. It is remarkable that the most minute examples occur at Glencart, Dalry, near the top of the Upper Limestone Series; the peculiar character of the deposit in which they were found was described by Dr. John Young, and also referred to by me.

Aclisina and *Aclisoides* are not associated together in this paper on account of a supposed close relationship, but because, owing to a superficial resemblance, a species of the latter had been mistaken for a member of the former. I have discussed the possible affinities of *Aclisina*, and have shown that it bears a great likeness to *Promathildia* Andreæ, which genus was then included by some palæontologists in the family Turritellidæ. Koken considered that *Aclisina* might be the direct forerunner of certain *Turritellæ*. M. Cossmann has since created the family Mathildiidæ:[1] thus it is now a question whether *Aclisina* should not find a place there in proximity to *Promathildia*. If this were the case, *Aclisina* would be the most ancient member of the group as now constituted.

A far greater number of species of *Aclisina* have been found in Scotland than in any other country. Of the twenty-two recorded only one is peculiar to England, and one, or at most two, to Ireland. The former is the fossil described by Mr. Bolton as *Loxonema ashtonense* from the basement-beds of the Bristol Coalfield. One of the Irish species, *A. sulcatula* (McCoy), has not been observed elsewhere; the other, *A. polygyra* (McCoy), is probably conspecific with *A. elongata* (Fleming), but the holotype is so much embedded in the matrix that it is difficult to be certain of this.

With regard to the species occurring in Scotland, it may be

[1] 'Essais de Paléoconchologie Comparée,' vol. ix (1912) p. 2. After writing the above I received vol. x (1915) of this work, and I observe that on p. 259 M. Cossmann does not consider *Aclisina* to be related to *Turritella*, but states that 'l'intermédiaire entre *Loxonema* et *Mathildia* est manifeste.'

noted that the variety *exigua* of *Aclisina pulchra* De Koninck and *A. elongata* (Fleming) have the most extended range, the former making its appearance in the Calciferous Sandstone Series, and continuing throughout the Lower Limestone Series and the Upper Limestone Series into the Millstone Grit. In Belgium the species is only recorded from Tournai, where specimens attain a greater size than any Scottish variety that I have seen. *A. elongata* has a similar range in Scotland, except that it has not been recorded from the Millstone Grit. It also occurs in the Yoredale Series of England, and is probably represented in Ireland and Belgium. L. G. de Koninck figures a small gasteropod from Visé on pl. xxxiii, figs. 45 & 46, in 'Faune du Calcaire Carbonifère de Belgique' pt. iv, Ann. Mus. Roy. Hist. Nat. Belg. vol. viii (1883), which greatly resembles this species; but it is undescribed, as it was lost.

Eight species occur in both the Lower and the Upper Limestone Series: namely, *A. costatula*, *A. attenuata*, *A. aciculata*, *A. tenuistriata*, *A. quadrata*, *A. similis*, *A. striatissima*, and *A. ? multivolva*. Of these, *A. similis* and probably *A. striatissima* are found also in Belgium.

Five species are confined to the Lower Limestone Series: namely, *A. pusilla*, *A. parvula*, *A. terebra*, *A. elegantula*, and *A. venusta*.

Four are limited to the Upper Limestone Series: namely, *A. delicatula*, *A. faber*, *A. micula*, and *A. subelongata*.

A. grantonensis has only been found in the Calciferous Sandstone Series.

Of the two species referred to *Aclisoides*, *A. striatula* has the widest range, occurring in both the Lower and the Upper Limestone Series of Scotland, as well as in England, the Isle of Man, and Belgium; while *A. ? armstrongiana* is only known from the Lower Limestone Series of Scotland. This subgenus is confined to the Carboniferous Period.

In addition to the fourteen foreign Carboniferous species of *Aclisina* previously mentioned, three have been described by Miss Clara G. Mark,[1] and three others have been doubtfully referred to the genus by her; these latter, however, do not appear to possess the characteristic lines of growth. The three former are *A. formosa*, *A. conditi*, and *A. pumila*, from the Portersville Limestone, Conemaugh Formation.

Besides these, a new species from the Zechstein, *A. beneventa*,[2] has been described by E. Dietz, and also one from the Devonian, *A. fugitiva* Barrande, by Dr. Jaroslav Perner.[3]

This genus has been stated to range from the Devonian to the Permian: if, however, the species *A. obscura* Donald,[4] doubtfully

[1] Geol. Surv. Ohio, ser. 4, Bull. 17 (1912) p. 314 & pl. xvi, figs. 7–10.

[2] Jahrb. K. Preuss. Geol. Landesanst. vol. xxx, pt. i (1911) p. 475 & pl. xv, fig. 1.

[3] 'Système Silurien du Centre de la Bohême, vol. iv: Gastéropodes' vol. ii (1907) p. 372 & pl. cx, figs. 19–20.

[4] Q. J. G. S. vol. lviii (1902) p. 337 & pl. ix, fig. 12.

referred to it from the Silurian, prove to be a true member, its origin must be more ancient.

I am greatly indebted to both Mr. R. G. Carruthers and Mr. Peter Macnair for information respecting the horizons at which the Scottish species occur. Their views agree in the main with regard to the Upper Limestone Series. But for the Lower Limestone and Calciferous Sandstone Series I have been guided by Mr. Macnair, whose recent extensive studies of the stratigraphy of these beds have led him to differ from the Geological Survey. He considers that there is no marked break between the strata of the Calciferous Sandstone Series and the succeeding Lower Limestone Series, and refers to the latter all the sedimentary rocks (including the Hollybush Limestone) that occur above the Calciferous-Sandstone lavas of the West of Scotland.

In Proc. Geol. Assoc. vol. xxvi, pt. 3 (1915) p. 179, he describes the remarkably fine sections at Corrie Burn, Kilsyth (Stirlingshire), and on p. 181 sums up thus:

'The main points of difference between this reading of the succession and that of the Geological Survey is that in the north of Ayrshire they take the Dockra Limestone as the Hurlet, the four succeeding limestones being respectively the Blackhall, Main Hosie, Mid Hosie, and Top Hosie. In Fife they take the Seafield Limestone as the Hurlet; this is my Main Hosie. In the Bilston Burn, Midlothian, they take the Gilmerton Limestone as the Hurlet, whereas my Hurlet datum-line lies about 200 feet below the Gilmerton Limestone.'

Mr. Macnair regards the Dockra Limestone as underlying the Hurlet, and as being equivalent to the Blackbyre Limestone of Kilsyth, Campsie, and Hurlet. In several communications to the Geological Society of Glasgow, published in their Transactions during the years 1912–16, he supplies further details, and deals with the correlation of these strata with those in Lanarkshire.

No species of *Aclisina* and *Aclisoides* have been recorded from the Hurlet Limestone as here defined; this is not, however, remarkable, since they are mostly small forms, and Mr. John Smith [1] states that there is a great scarcity of fossils in this stratum.

The beds at Penton Linns (Dumfriesshire) have not been carefully zoned, therefore it is impossible to state the exact position of those from which the gasteropods here described are derived. The undersides of the slabs are crowded with *Productus longispinus* Sowerby, and there are numerous spines and fragments of the brachiopods above. Dr. J. Horne & Dr. B. N. Peach [2] give a short list of fossils from this locality in their account of the Canonbie Coalfield, and state that they recall the assemblage of organic remains of the Lower Limestone Series of Central Scotland.

The exact relationship of the Scottish strata with the English has not been thoroughly worked out, therefore the reference to

[1] Trans. Geol. Soc. Glasgow, vol. xiv, pt. ii (1911) p. 141.
[2] Trans. Roy. Soc. Edin. vol. xl (1903) p. 850.

the late Dr. Arthur Vaughan's zones can only be regarded as temporary and approximate.

Prof. E. J. Garwood has very kindly given me his views, based on the information at present available. He considers the Lower Limestone Series to be homotaxial with D_1-D_2, and the Upper Limestone Series with D_y-? D_3. The Settle Limestone is S_2 and D_1. Widdale Fell, Mosedale, is D_y.

The Upper Limestone of Poolvash (Isle of Man) is probably D_1 D_2. Mr. J. Smith's gasteropoda came from the partly dolomitized upper limestone east of the Balladoole Fault, Poolvash. He believes the horizon to be lower than that of the Hurlet Limestone of the West of Scotland.

With regard to the Irish localities, Cullion, Draperstown, and Carrickoughter, Kesh, Prof. G. A. J. Cole states that the districts require careful zoning before the exact positions can be ascertained. Dr. Vaughan considered that the former might be homotaxial with C_1 of the Avon Section. The latter is probably at a much higher horizon.

A table is appended (pp. 64–67) with names of species, localities, and the Scottish horizons. These latter are, for the greater part, called after the characteristic limestone; the fossils, however, are by no means restricted to that stratum, but are frequently found in the associated shales. There being very few records outside Scotland, it has not been considered necessary to give additional columns for their horizons, more especially as they are not very precisely defined at present. Since the localities are fully dealt with here, they are given under the descriptions only in the case of holotypes and rarer species. Also those alone from which I have actually seen specimens myself are stated. I have examined many of the gasteropoda to which names have been given in the Scottish Geological-Survey lists, and I find that these names are not in all cases to be depended upon. Confusion has probably arisen from grafting more recent nomenclature on the older. For instance, I have met with five distinct species referable to at least two genera, all grouped under one specific name, which was not applicable to any one of them. On the other hand, a single species occurs under two different names.

In order to save space, only such parts of the synonymy are repeated as are essential for clearness.

Most of the small specimens were drawn with the camera lucida on the microscope, and the approximate magnification is given in each case.

For the loan of specimens I offer my most hearty thanks to those in charge of the Geological Survey Collections in London and Edinburgh; to the Council of the Hancock Museum, Newcastle-upon-Tyne; to the late Prof. McKenny Hughes, Sedgwick Museum, Cambridge; to Dr. Ritchie, Royal Scottish Museum, Edinburgh; to Mr. Peter Macnair, Glasgow Museum, Kelvingrove; and to Mr. Herbert Bolton, Bristol Museum. I desire also to express my gratitude to Mr. Robert Dunlop, Dunfermline,

TABLE ILLUSTRATING THE DISTRIBUTION IN SCOTLAND OF *ACLISINA* AND *ACLISOIDES*.

Genus.	Species.	Variety.	Localities.[1]	SCOTLAND. Lower Carboniferous. Calc. Ste. Ser.: Cementstone Group.	Oil-Shale Group.	Lower Limestone Series.: Hollybush Limestone.	Blackbyre Limestone.	Hurlet Alum Shale.	Blackhall Limestone.	Main Hosie.	Upper Limestone Series.: Index Limestone.	Orchard Limestone.	Calmy Limestone.	Castlecary Limestone.	Horizon undetermined.	Upr. Carb.: Millstone Grit.	Page
Aclisina	*aciculata* Donald.		Craigenglen.			×											77
			Law, Dalry; Dykes, Kilbirnie.				×										
			Brankam Hall; Capelrig.							×							
			Gillfoot, Carluke.									×					
			High Smithston, Kilwinning.												×		
Aclisina	*ashtonensis* (Bolton).		Ashton Vale Colliery.														78
	attenuata Donald.		Craigenglen.			×											70
			Dykes.				×										
			Woodmill, Dunfermline.						×								
			High Blantyre; Brankam							×							
			Hall; Capelrig.							×							
			Robroyston; Gair, Carluke.										×				
			Glencart, Dalry.											×			
			High Smithston.												×		
Aclisina	*costatula* Donald.		Penton[2]; Craigenglen.			×											70
			Law; Cunningham Baidland.				×										
			Woodmill, Dunfermline.						×								
			High Blantyre; Brankam Hall; Capelrig; Hairmyres.							×							
			Boghead, Quarter.							×							
			Dernshaw, Stewarton; Penbreck,[3] Muirkirk.								×						
			Orchard.									×					
			Brodlie, Dalry; Wellwood,[4] Muirkirk.										×				
			Glencart.											×			
			High Smithston and Moss Mullock, Kilwinning.												×		

Aclisina	*costatula*	*dubia* Donald.	Craigenglen.			×											70
			High Smithston; Moss Mullock.												×		
Aclisina	***delicatula***, **sp. nov.**		Glencart.											×			71
	elegantula Donald.		Law; Dykes.				×										74
	elongata (Fleming).		Randerstone (Fife).	×													72
			Craigenglen; Penton[2]; Crawfield, Beith.			×											
			Law; Dykes.				×										
			Elie (Fife).					×									
			Brankam Hall; High Blantyre; Capelrig; Boghead.							××							
			Orchard; Thornliebank.									×					
			Wellwood.[4]										×				
			Glencart.											×			
			Moss Mullock.												×		
			Widdale Fell, Mosedale.														
Aclisina	*elongata*	*cingulata* Donald.	Craigenglen; Penton[2]; Crawfield.			××											73
			High Blantyre; Capelrig.							×							
			Glencart.											×			
Aclisina	*elongata*	*varians* Donald.	Craigenglen.			×											73
			Dykes.				×										
			Elie.					×									
			Brankam Hall; Capelrig.							×							
Aclisina	***faber***, **sp. nov.**		High Smithston.												×		70
			Glencart.											×			
	grantonensis Donald.		Randerstone? Woodhall, Edinburgh.	×	×												76
	micula, **sp. nov.**		Moss Mullock; High Smithston.												×		71
	? *multivolva* Donald.		Bankend; Brockley.				×										77
			Glencart.											×			
			Moss Mullock.												×		
	parvula Donald.		Crawfield.			×											75
			Law; Dykes.				×										

[1] The type locality is in every case printed in spaced letters.
[2] The beds at this locality possess a fauna suggestive of the lower part of the Lower Limestone Series, but they have not been accurately zoned.
[3] Referred to the Index Limestone with a query, by Mr. J. Smith.
[4] A short distance below the Calmy Limestone, according to Mr. J. Smith.

Table (*continued*).

Genus.	Species.	Variety.	Localities.[1]	SCOTLAND. Lower Carboniferous. Calc. Ste. Ser. Cementstone Group.	Oil-Shale Group.	Lower Limestone Series. Hollybush Limestone.	Blackbyre Limestone.	Hurlet Alum Shale.	Blackhall Limestone.	Main Hosie.	Upper Limestone Series. Index Limestone.	Orchard Limestone.	Calmy Limestone.	Castlecary Limestone.	Horizon un-determined.	Upr. Carb. Millstone Grit.	Page
Aclisina	*polygyra* (McCoy).		Cullion, Draperstown.														73
	pulchra De Koninck.		Tournai.														68
	pulchra	*exigua* Longstaff.	Randerstone.	×													68
			Craigenglen.			×											
			Law; Dykes.				×										
			Brankam Hall; Raesgill, Carluke?							×							
			Swindridge Muir; Dernshaw, Stewarton; Highfield, Dalry; Auchenbeg, Lesmahagow; Pollokshaws.								× × × ×						
			Orchard; Thornliebank.									×					
			Robroyston; Bowertrapping.										×				
			Glencart.											×			
			High Smithston.												×		
			Glenboig (Lanarkshire).													×	
Aclisina	*pulchra*	*intermedia* Donald.	Law.				×										69
	pusilla Donald.		Law; Dykes.				×										72
	quadrata Donald.		Law.				×										76
			Moss Mullock; High Smithston.												×		
	similis Donald.		Law; Dykes.				×										71
			Glencart.											×			
			High Smithston.												×		
			Visé.														

Aclisina striatissima Donald.	Law; Dykes.				×										75
	High Smithston.												×		
subelongata, sp. nov.	Glencart.											×			74
	Moss Mullock.												×		
? *sulcatula* (McCoy).	Carrickoughter, Kesh.														74
terebra Donald.	Crawfield.			×											75
	Law.				×										
tenuistriata Donald.	Penton[2]; Craigenglen;			×											76
	Crawfield ?			×											
	Law.				×										
	Boghead ?							×							
	Moss Mullock.												×		
Aclisina venusta, sp. nov.	Law.				×										69
Genus															
Murchisonia D'Archiac & De Verneuil.															
Subgenus Species															
Aclisoides Donald. *striatula* (De Koninck).	Craigenglen; Strathavon.			×											78
	Law.				×										
	Dernshaw.								×						
	Brodlie.										×				
	Glencart.											×			
	Settle.														
	Widdale Fell, Mosedale.														
	Poolvash (Isle of Man).														
	Visé.														
	Tournai.														
Aclisoides ? *armstrongiana* Donald.	Law; Dykes.				×										82

[1] The type locality is in every case printed in spaced letters.
[2] The beds at this locality possess a fauna suggestive of the lower part of the Lower Limestone Series, but they have not been accurately zoned.

Mr. James Wright, Kirkcaldy, and Mr. John Smith, Dalry, for the privilege of examining examples in their private collections. Further, for assistance in many ways I am greatly obliged to Dr. A. Smith Woodward, F.R.S., Dr. F. A. Bather, F.R.S., Prof. E. J. Garwood, F.R.S., Dr. F. L. Kitchin, the late Mr. G. C. Crick, Dr. F. R. Cowper Reed, Dr. Lee, Prof. S. H. Reynolds, Prof. G. A. J. Cole, M. Louis Dollo, and M. Douvillé.

Genus Aclisina De Koninck.

Aclisina pulchra De Koninck. (Pl. V, figs. 1 & 2 *a*–2 *b*.)

Aclisina pulchra De Koninck, 1881, 'Faune Calc. Carb. Belg.' pt. iii, Ann. Mus. Roy. Hist. Nat. Belg. vol. vi, p. 87 & pl. vii, figs. 26–27.

Remarks.—L. G. de Koninck represents this species as having the whorls ornamented by seven or eight spiral grooves and ridges of equal size. In reality, however, the upper ridges, from 1 to 3 in number, are finer than the three or four below, and on the body-whorl these latter are followed by numerous still finer ridges, one or two of which frequently show above the suture on the penultimate whorl. On the earlier whorls only one of the three finer ridges exists, it is immediately below the suture. None of the Belgian specimens that I have seen has the apex intact. The sigmoidal form of the outer lip is well preserved in a specimen (Pl. V, fig. 2) in the collection of Canon H. de Dorlodot: this character is only indicated by the lines of growth in all the other species of the genus that I have examined.

So far, I have not met with any typical specimens of this species in the British Isles.

Holotype.—*Op. cit.* pl. vii, figs. 26 & 27. Also Pl. V, fig. 1 of this paper.

There are two smaller examples associated with the holotype in the Musée Royale d'Histoire Naturelle at Brussels, also a good specimen in the British Museum (Natural History), and I have two others purchased from M. Piret.

Locality and horizon.—Tournai (Assise i).

Aclisina pulchra, var. exigua, nom. nov.

Aclisina pulchra var. *tenuis* (De Koninck) Donald, 1898, Q. J. G. S. vol. liv, p. 52 & pl. iii, figs. 1–4.

Remarks.—I referred a small Scottish variety of *A. pulchra* to *Murchisonia tenuis* De Koninck, because I found that it agreed with the best-preserved shells on a tablet so named in the Brussels Museum. During a subsequent visit a further examination of this tablet convinced me that there were two distinct species on it. The specimen marked as holotype is much worn, and has only three somewhat coarse threads ornamenting the whorl; two of the eight examples associated with it are the same, and they all look like immature shells. The remaining five are different, and are conspecific with the Scottish shells. These latter greatly resemble

the typical *A. pulchra*, but they are much smaller and rather more slender. At least eight and twenty Scottish specimens are remarkable for having the protoconch intact, and some also exhibit the characteristic sigmoidal lines of growth.

Holotype.—*Op. cit.* pl. iii, fig. 2. In the Neilson Collection, Royal Scottish Museum, Edinburgh.

Locality and horizon.—Robroyston, Glasgow, in the Upper Limestone Series.

Unfortunately the finer specimen (fig. 1) from Swindridge Muir, Ayrshire, also in the Upper Limestone Series, has perished by fire. There are, however, numerous examples from this locality in the Young, Neilson, and my own collections.

Specimens in Mr. J. Smith's collection from the Index Limestone at Highfield, Dalry, and Dernshaw, Stewarton, have the protoconch preserved, as well as those previously mentioned from the last-named locality.

Aclisina pulchra, var. intermedia Donald.

Aclisina pulchra, var. *intermedia* Donald, 1898, *op. cit.* p. 53 & pl. iii, figs. 5–5*a*.

Remarks.—Specimens previously referred to this variety from Swindridge Muir are most probably *A. costatula*.

Holotype.—*Op. cit.* pl. iii, figs. 5 & 5*a*. Bennie Collection, Royal Scottish Museum, Edinburgh.

Locality and horizon.—Law, Dalry (Ayrshire), in the Lower Limestone Series.

Aclisina venusta, sp. nov. (Pl. V, figs. 3*a* & 3*b*.)

Diagnosis.—Shell elongated, conical, composed of more than seven whorls. Whorls convex, ornamented on the lower part by four threads, the two upper of which are the strongest and farthest apart; midway between these and the suture are two finer ones, and on the body-whorl there are two additional fine threads below. Sutures deep. Base convex, slightly produced. Inner lip reflected. Columella nearly straight.

Remarks.—From *A. pulchra* this species may be distinguished by being more slender and having more regularly convex whorls. It is most like the variety *intermedia*, but is of much greater size, and has also two fine threads on the upper part of the whorl. We have, however, only one example of each of these forms; it is therefore possible that the discovery of intermediate links might prove them to be the extremes of a single species or variety.

Holotype.—Pl. V, figs. 3*a* & 3*b*, Bennie Collection, Royal Scottish Museum, Edinburgh.

Dimensions.—Length = 8 millimetres; width = 3 mm.

Locality and horizon.—Law, Dalry, in the Lower Limestone Series.

ACLISINA FABER, sp. nov. (Pl. V, figs. 4 & 5 *a*–5 *c*.)

Diagnosis.—Shell small, conical, composed of more than nine whorls. Whorls broad, convex, slightly flattened above and subangular near the middle. Lower part ornamented by six moderately strong threads with two additional ones on the body-whorl; upper part ornamented by three fine threads; base covered by numerous still finer ones. Protoconch composed of little more than one smooth volution, moderately raised and slightly overhanging the succeeding whorl. Aperture subcircular. Columella nearly straight. Inner lip reflected.

Remarks.—This species somewhat resembles *A. pulchra*, but it has more convex whorls ornamented by finer and more numerous threads, also the protoconch is more orbicular and not so erect.

Holotype.—The larger specimen represented in Pl. V, fig. 4, must be regarded as the holotype; it consists of nine whorls the length of which = 6 mm., and the width = 2·5 mm. The smaller shell (fig. 5) is remarkable for having the protoconch intact; its length = 1·75 mm. Both are in Mr. John Smith's collection.

Locality and horizon.—High Smithston, Kilwinning (Ayrshire), in the Upper Limestone Series.

Three small shells in my own collection appear to belong to this species. They are from Glencart, Dalry, also in the Upper Limestone Series.

ACLISINA COSTATULA Donald.

Aclisina costatula Donald, 1898, *op. cit.* p. 56 & pl. iii, figs. 12–14.

Holotype.—*Op. cit.* pl. iii, fig. 12. Longstaff Collection.

Locality and horizon.—Penton Linns, Liddel Water (Dumfriesshire). Lower Limestone Series.

ACLISINA COSTATULA, var. DUBIA Donald.

Aclisina costatula var. *dubia*, Donald, 1898, *op. cit.* p. 57 & pl. iii, fig. 15.

Remarks.—The examination of a large number of specimens shows that *A. costatula* exhibits a certain amount of variation. I suggested the name *dubia* for a large variety having somewhat higher whorls. Unfortunately the original example has perished by fire with the late Mr. Thomson's collection. There is, however, a shell in Mr. J. Smith's collection greatly resembling it in every way. It has six whorls intact, which have a length of 5·5 millimetres.

Locality and horizon.—Whereas the original was from Craigenglen, Campsie (Stirlingshire), in the Lower Limestone Series, this specimen is from Moss Mullock, in the Upper Limestone Series.

ACLISINA ATTENUATA Donald.

Aclisina attenuata Donald, 1898, *op. cit.* p. 58 & pl. iv, figs. 2–3.

Holotype.—*Op. cit.* pl. iv. fig. 2. Longstaff Collection.

Locality and horizon.—Glencart, Dalry, in the Upper Limestone Series.

ACLISINA DELICATULA, sp. nov. (Pl. V, figs. 6 *a*–6 *c*.)

Diagnosis.—Shell slender, composed of eleven gradually increasing whorls. Whorls convex, broad and low. Ornamentation consisting of five moderately strong threads on the lower part of each whorl, with numerous additional finer ones below on the body-whorl; higher part of the whorl apparently smooth. Lines of growth unknown. Apex broad and nearly flat. Protoconch consisting of about one smooth whorl coiled on almost the same plane as the rest of the spire to which it is attached. Base convex, but little produced. No umbilicus. Aperture ovoid. Columella nearly straight, curving round at the bottom to meet the outer lip. Inner lip reflected on the body-whorl.

Remarks.—This species resembles *A. costatula* in ornamentation, but the form is not so slender and the whorls are more convex. The protoconch of the only known specimen is intact, but is somewhat worn, and probably is slightly crushed, so that it may not originally have been so flat.

Holotype.—Pl. V, figs. 6 *a*–6 *c*. In my own collection, given to me by the late Dr. John Young.

Dimensions.—Length=4·25 millimetres; width=1·4 mm.

Locality and horizon.—Glencart, Dalry, in the Upper Limestone Series.

ACLISINA MICULA, sp. nov. (Pl. V, figs. 7 *a* & 7 *b*.)

Diagnosis.—Shell elongated, composed of about ten slightly convex whorls. Whorls broad, ornamented on the lower two-thirds by four threads, the two upper are the strongest and farthest apart; two additional fine threads on the body-whorl. Sutures of moderate depth. Base not produced. Aperture rounded. Protoconch flat and broad, attached to, or but slightly raised from, the spire.

Remarks.—*Aclisina micula* may be distinguished from *A. costatula* by its greater spiral angle, shallower sutures, more compactly coiled whorls, and in the protoconch being attached to the spire instead of standing up. It differs also from *A. attenuata* in being less slender, and in the lower threads being coarser. The only two specimens that I have met with show the protoconch intact; it adheres closely on one, while on the other (the holotype) it is very slightly raised.

Holotype.—Pl. V, figs. 7 *a* & 7 *b*. Smith Collection.

Dimensions.—Length=3·5 millimetres; width=1 mm.

Locality and horizon. High Smithston, Kilwinning. Upper Limestone Series.

The other example is from Moss Mullock, Kilwinning, at the same horizon and in the same collection.

ACLISINA SIMILIS Donald. (Pl. V, fig. 8.)

Aclisina similis Donald, 1898, *op. cit.* p. 57 & pl. iii, fig. 16, pl. iv, fig. 1.
Aclisina pusilla Donald, 1898, pars, *op. cit.* p. 63 & pl. iv, fig. 15 [exclude figs. 14, 14 *a*, & 14 *b*.]

Remarks.—About sixteen specimens of this species have been examined, but only one has the protoconch intact (Pl. V, fig. 8). It is in Mr. J. Smith's collection, and was found by him at High Smithston, in the Upper Limestone Series.

Holotype.—*Op. cit.* pl. iv, fig. 1. Bennie Collection, Royal Scottish Museum, Edinburgh.

Locality and horizon.—Law, Dalry, in the Lower Limestone Series.

Aclisina pusilla Donald. (Pl. V, fig. 9.)

Aclisina pusilla Donald, 1898, *op. cit.* p. 63 & pl. iv, figs. 14, 14 *a*, & 14 *b* [exclude fig. 15].
? *Aclisina parvula* Donald, 1898, pars, *op. cit.* p. 64 & pl. v, figs. 2, 2 *a*, & 2 *b*.

Remarks.—This species is distinguished by its slender form, flattened whorls, and relatively broad, flat apex. The examination of a number of specimens shows that there is a slight variation in the strength of the ornamenting threads. The example of which a portion of a whorl is figured (*op. cit.* pl. iv, fig. 15), from Glencart, is really *A. similis*, a species which *A. pusilla* greatly resembles; but the latter is smaller, the whorls are lower, and the protoconch is flat. Several examples have the apex intact. It is probable that figs. 2, 2 *a*, & 2 *b* in pl. v. *op. cit.* represent an immature form of this species.

Holotype.—*Op. cit.* pl. iv, fig. 14. A figure (Pl. V, fig. 9) of the protoconch of this shell is given, as that previously drawn belonged to another specimen. Smith Collection.

Locality and horizon.—Law, Dalry. Lower Limestone Series.

Besides the holotype there are six additional specimens in the Bennie Collection, and one in the Young Collection from Law, Dalry; also seven from Dykes, Kilbirnie, in the Smith Collection. They are all from the Lower Limestone Series.

Aclisina elongata (Fleming). (Pl. V, figs. 10–12.)

Aclisina elongata (Fleming) Donald, 1898, *op. cit.* p. 54 & pl. iii, figs. 6–6 *a*.

Remarks.—It is unfortunate that the holotype should be an exceedingly small specimen with the apex broken, consisting of four and a half whorls in a length of 2 millimetres. All the gasteropods from the same locality have similar dimensions. Most of the examples from Penton are of greater size; that figured in *op. cit.* pl. iii, fig. 6, is the largest, but it is not well preserved, being greatly crushed. The enlarged portion of a whorl (fig. 6 *a*) is part of a fragment of a shell, showing the ornamentation and contour distinctly, and on the same slab with it are two smaller specimens fairly preserved, one of which has twelve whorls with a length of 5·5 millimetres. Many of the examples from Law, Dalry, exhibit the ornamentation and contour well, as they are preserved in such a manner as to be easily detached from the matrix. Mr. R. Dunlop possesses an exceedingly fine series of about forty

specimens from Elie (Fife), which show a certain amount of variation in the ornamentation, there being intermediate forms merging into the variety *varians*. In Mr. J. Smith's collection there is a remarkably perfect young example with apex and aperture intact; it consists of seven whorls besides the protoconch in a length of 2·25 millimetres (Pl. V, fig. 12). It is from Dykes, Kilbirnie (Ayrshire), in the Lower Limestone Series. One of the best preserved shells was found at Crawfield, Beith, and is figured (Pl. V, fig. 11).

Holotype.—Ure Collection, Royal Society, Edinburgh. Pl. V, fig. 10.

Locality and horizon.—Lauriston (Brankam Hall), Lanarkshire, in the Lower Limestone Series.

ACLISINA ELONGATA, var. VARIANS Donald. (Pl. V, fig. 15.)

Aclisina elongata, var. *varians* Donald, 1898, *op. cit.* p. 55 & pl. iii, fig. 9.

Remarks.—This variety is especially well represented at Craigenglen. In Mr. J. Smith's collection there are two young specimens with the protoconch intact; the back view of one is given in Pl. V, fig. 15. They are from the Lower Limestone Series at Dykes, Kilbirnie.

Holotype.—*Op. cit.* pl. iii, fig. 9. Ure Collection, Royal Society, Edinburgh.

Locality and horizon.—Lauriston (Brankam Hall), in the Lower Limestone Series.

ACLISINA ELONGATA, var. CINGULATA Donald. (Pl. V, figs. 13 & 14.)

Aclisina elongata, var. *cingulata* Donald, 1898, *op. cit.* p. 55 & pl. iii, figs. 10–10 *a*; ? figs. 7 *a*–7 *c*.

Remarks.—This variety is distinguished from the type by the whorls being usually higher, as well as by the difference in ornamentation. An example larger than that previously figured is given in Pl. V, figs. 13 *a* & 13 *b*, as it shows the variation in the ornamenting threads more distinctly. It is from the same locality, and is in the same collection. The protoconch previously referred to this variety (pl. iii, figs. 7 *a*–7 *c*) most probably belongs to *A. tenuistriata*. The specimen is contorted, and the ornamentation is indistinct. Mr. J. Smith has a remarkably well-preserved example of this variety with the protoconch, which is figured in Pl. V, fig. 14. Since the protoconchs of the typical form and the two varieties resemble one another, only one figure of each is given, taken from different aspects. They are all from Dykes.

Holotype.—*Op. cit.* pl. iii, figs. 10 & 10 *a*. Young Collection, Glasgow Museum.

Locality and horizon.—Glencart, Dalry, in the Upper Limestone Series.

ACLISINA POLYGYRA (McCoy).

Aclisina polygyra McCoy, Donald, 1898, *op. cit.* p. 71 & pl. iii, fig. 11, quoted as *Loxonema polygyra* McCoy on p. 55, and referred with doubt to *Aclisina elongata* (Fleming).

Holotype.—'Syn. Char. Carb. Foss. Irel.' pl. iii, fig. 1. Griffith Collection, National Museum, Dublin.

Locality and horizon.—Cullion, Draperstown. Lower part of the Carboniferous Limestone.

ACLISINA ? SULCATULA (McCoy).

Loxonema sulcatula McCoy, 1844, 'Synopsis of the Characters of the Carboniferous Limestone Fossils of Ireland' p. 30 & pl. v, fig. 6.
Aclisina ? *sulcatula* Donald, 1898, Q. J. G. S. vol. liv, p. 64 & pl. v, fig. 3.

Holotype.—'Syn. Char. Carb. Foss. Irel.' pl. v, fig. 6, and Q. J. G. S. vol. liv, pl. v, fig. 3. Griffith Collection, National Museum, Dublin.

Locality and horizon.—Carrickoughter, Kesh. Probably high in the Lower Carboniferous Series.

ACLISINA SUBELONGATA, sp. nov. (Pl. VI, fig. 1.)

Diagnosis.—Shell elongated, turriculated, composed of more than ten whorls. Whorls angular, flattened above, slightly convex below. Ornamentation consisting of a strong thread on the angle with one above and three below, space immediately above the angle rather wider than those below, four or five additional very fine threads on the base. Aperture not well preserved. Columella nearly straight. Sutures deep.

Remarks.—This species greatly resembles *A. elongata* (Fleming), but the spiral angle is rather wider, the whorls are more angular, and the threads ornamenting the spire fewer and coarser.

Holotype.—Pl. VI, fig. 1. Though small this specimen is almost entire. Length = 4·25 millimetres; width = 1·25 mm. In Mr. John Smith's collection.

Locality and horizon.—Moss Mullock, Kilwinning, in the Upper Limestone Series.

There is another example from this locality in the same collection, as well as one from Glencart, Dalry, also in the Upper Limestone Series. The Young Collection, Kelvingrove Museum, Glasgow, contains two specimens from Glencart, one of which is bigger, having nine whorls in a length of 8 mm.; both apex and base are broken. A shell in the Museum of Practical Geology, London, appears to belong to this species; it is, however, much larger and is somewhat crushed. The exact locality is not stated, only 'Glasgow' being given. It has the appearance of specimens derived from the Lower Limestone Series, where they frequently attain a greater size than those from the Upper Limestone Series. Its length = 14 millimetres for seven whorls, the greatest width of which = 5·5 mm.

ACLISINA ELEGANTULA Donald. (Pl. VI, fig. 2.)

Aclisina elegantula Donald, 1898, *op. cit.* p. 62 & pl. iv, figs. 13, 13 *a*–13 *c*.

Remarks.—Besides the specimens previously mentioned from Law, Dalry, and Cunninghambaidland (Ayrshire), Mr. Smith's

collection contains some from Dykes, Kilbirnie, one of which has the protoconch well preserved. A new drawing (Pl. VI, fig. 2) of the protoconch of the original example is given, as the figure 13 *b* does not show that it slightly overhangs the spire. With the exception of the holotype most of the specimens found are small, and if it were not for the existence of a shell of intermediate size, these small examples might be considered to constitute a distinct species.

Holotype.—*Op. cit.* pl. iv, fig. 13. Collection of Mr. John Smith.

Locality and horizon.—Law, Dalry, in the Lower Limestone Series.

The medium-sized specimen is from the same locality, and is in the same collection.

ACLISINA PARVULA Donald.

Aclisina parvula Donald, 1898, *op. cit.* p. 64 & pl. v, fig. 1, ? fig. 2.

Remarks.—*A. parvula* differs from *A. pusilla* by its more convex whorls, deeper sutures, and greater spiral angle. There are two additional specimens in the collections of Mr. Bennie and Mr. Smith, which occurred respectively at Law, Dalry, and Dykes, Kilbirnie, in the Lower Limestone Series. I feel doubtful about the specimen represented by fig. 2 being really this species, and I think that it is most probably an immature example of *A. pusilla*.

Holotype.—*Op. cit.* pl. v, fig. 1. Longstaff Collection.

Locality and horizon.—Crawfield Quarry, Beith (Ayrshire), in the Lower Limestone Series.

ACLISINA TEREBRA Donald.

Aclisina terebra Donald, 1898, *op. cit.* p. 63 & pl. iv, fig. 16.

Holotype.—*Op. cit.* pl. iv, fig. 16. Young Collection, Kelvingrove Museum, Glasgow.

Locality and horizon.—Crawfield Quarry, Beith, in the Lower Limestone Series.

There is another specimen in my own collection from Law, Dalry, also in the Lower Limestone Series.

ACLISINA STRIATISSIMA Donald. (Pl. VI, figs. 3 & 4.)

Aclisina quadrata var. *striatissima* Donald, 1898, *op. cit.* p. 61 & pl. iv, fig. 12.

Remarks.—I consider that this form should be regarded as a distinct species rather than as a variety of *A. quadrata*. Unfortunately, the shell originally figured has perished with the Hunter-Selkirk Collection. I therefore suggest as holotype the specimen mentioned at that time as having been presented to me by Dr. John Young, from the same locality. It is broken, and only six whorls remain, which = 3·25 millimetres in length, and not quite 1 mm. in width. The surface is well preserved, and shows the ornamenting striæ distinctly. I figure now the protoconch

(Pl. VI, fig. 4) of another small example, also given to me by Dr. John Young, as it is slightly flatter than that of the shell originally figured. Besides the specimens formerly mentioned, Mr. J. Smith has four from the Lower Limestone Series of Dykes, Kilbirnie, and one from the Upper Limestone Series of High Smithston, Kilwinning. In the Liége Museum I observed a shell from Visé resembling this in shape and ornamentation, but much larger: the four lower whorls, which alone are preserved, have a length of 5·5 millimetres and greatest width of 2·25 mm.

Holotype.—Pl. VI, fig. 3. Longstaff Collection.

Locality and horizon.—Law, Dalry, in the Lower Limestone Series.

ACLISINA TENUISTRIATA Donald. (Pl. VI, fig. 5.)

Aclisina tenuistriata Donald, 1898, *op. cit.* p. 60 & pl. iv, fig. 10.
? *Aclisina elongata*, var. *cingulata* Donald, 1898, pars, *op. cit.* p. 55 & pl. iii, figs. 7 *a*–7 *c* [exclude figs. 10 & 10 *a*].

Remarks.—As this species appears to be rare, it is interesting to record that Mr. J. Smith has three additional well preserved specimens, one from Moss Mullock, in the Upper Limestone Series, one from Craigenglen, and the third from Law, Dalry, in the Lower Limestone Series. He has also two worn shells, which probably belong to this species, from the last-named locality. The example from Moss Mullock has the protoconch intact: it stands up detached from the post-embryonic whorl, and is nearly orbicular in form.

Holotype.—*Op. cit.* pl. iv, fig. 10. Longstaff Collection.

Locality and horizon.—Penton Linns, Liddel Water (Dumfries), in the Lower Limestone Series.

ACLISINA GRANTONENSIS Donald.

Aclisina grantonensis Donald, 1898, *op. cit.* p. 60 & pl. iv, figs. 7–9.

Holotype.—*Op. cit.* pl. iv, fig. 7. Geological Survey Collection, Royal Scottish Museum, Edinburgh.

Locality and horizon.—Woodhall, near Edinburgh, in the Calciferous Sandstone Series. Four specimens in the Kirkby Collection, Hancock Museum, Newcastle-upon-Tyne, appear to agree with this species. They are from Randerstone Castle, also in the Calciferous Sandstone Series.

ACLISINA QUADRATA Donald.

Aclisina quadrata Donald, 1898, *op. cit.* p. 61 & pl. iv, fig. 11.

Remarks.—Since this is one of the rarer species, it is worth noting the existence (in Mr. J. Smith's collection) of a specimen from the same locality as the holotype, and also of others from High Smithston and Moss Mullock, Kilwinning, in the Upper Limestone Series.

Holotype.—*Op. cit.* pl. iv, fig. 11. Bennie Collection, Royal Scottish Museum, Edinburgh.

Locality and horizon.—Law, Dalry, in the Lower Limestone Series.

Aclisina aciculata Donald. (Pl. VI, fig. 6.)

Aclisina aciculata Donald, 1898, *op. cit.* p. 59 & pl. iv, figs. 4–6.

Remarks.—In addition to the specimens previously recorded, there are twenty in Mr. John Smith's collection, six of which have the protoconch preserved: it is like that figured (*op. cit.* pl. iv, figs. 6 *a*–6 *c*). As the shell in the Hunter-Selkirk Collection, from which these drawings were made, has been destroyed by fire, it is especially fortunate that more examples are available. Two of the specimens not only have the protoconch raised, but the three higher whorls of the spire are remarkably drawn out and loosely coiled (Pl. VI, fig. 6). They are all from Dykes, Kilbirnie; that in the Hunter-Selkirk Collection was from Law, Dalry. Both localities are in the Lower Limestone Series.

Holotype.—*Op. cit.* pl. iv, fig. 4. Young Collection, Kelvingrove Museum, Glasgow.

Locality and horizon.—Gillfoot, Carluke (Lanarkshire), in the Upper Limestone Series.

Aclisina? multivolva, sp. nov. (Pl. VI, figs. 7 & 8.)

Diagnosis.—Shell elongated, turriculated, composed of more than nine gradually increasing whorls. Whorls angular near the middle, flat or slightly concave above, flat or barely convex below. Ornamentation consisting of a strong thread on the angle with three below, the lowest of which is only seen on the body-whorl and at the suture of the anterior whorls of the spire; above, there is a strong thread with a finer one close to it, and on one of the whorls there is an indication of a still finer thread above. Sutures deep. Base rather flat. Columella nearly straight. Apex and aperture unknown.

Remarks.—This species is most like *A. subelongata*, but differs in being more slender, and in having fewer and stronger ornamenting threads below the angle, while there is an additional finer one above.

It is impossible to place the species with certainty, as neither protoconch, aperture, nor lines of growth are preserved: it is therefore only referred to *Aclisina* provisionally.

I have met with six specimens, three of which are very small, and one is also more slender. This last is in the late Dr. John Young's collection, and occurred in the Upper Limestone Series at Glencart. The other two belong to Mr. J. Smith, and were also found in the Upper Limestone Series. The remaining three are of greater size, otherwise they exhibit similar characters in form and ornamentation. They are from the Lower Limestone Series, where it is not unusual for specimens of much larger dimensions to occur. One has seven whorls in a length of 11·5 millimetres, and the greatest width = 4·5 mm. Originally it must have been more elongated, for it is compressed upwards, causing the lower whorls to be broader and shorter. This example is from Bankend (Lanarkshire). Only the anterior portions of the other two exist, consisting

of five and four whorls respectively. They are from Brockley, Lesmahagow.

Holotype.—I would select as holotype the smaller of Mr. Smith's specimens, as it is best preserved (Pl. VI, fig. 7). It consists of seven and a half whorls, the length of which = 4·25 millimetres and width = 1·25 mm.

Locality.—Moss Mullock.

ACLISINA ASHTONENSIS (Bolton). (Pl. VI, fig. 9.)

Loxonema ashtonense Bolton, 1907, Q. J. G. S. vol. lxiii, p. 464 & pl. xxx, figs. 17 *a*–17 *c*.

Remarks.—Mr. Bolton kindly lent me the holotype and numerous other specimens of this species from the same locality. I found that the lines of growth were discernible on three examples, and that they indicate the form of aperture characteristic of *Aclisina*. A figure of one of these is given in this paper (Pl. VI, fig. 9). On the later whorls there is a certain amount of irregularity in the ornamenting striæ, three or four near the middle are generally stronger than the others, and the spaces between them are wider, while on the earlier whorls only one of the spaces is wider; sometimes very fine striæ are intercalated between the coarser striæ. This species greatly resembles *A. robusta* Stevens,[1] from the Coal Measures of Danville (Illinois), but it is somewhat smaller, the upper part of the whorl is flatter, and the lines of growth are more oblique.

Holotype.—*Op. cit.* pl. xxx, fig. 17 *a*, Bolton Collection, Bristol Museum.

Locality and horizon.—Ashton Vale Colliery, in the Basement-Beds of the Bristol Coalfield.

Genus MURCHISONIA D'Archiac & De Verneuil.

Subgenus ACLISOIDES Donald.

ACLISOIDES STRIATULA (De Koninck). (Pl. VI, figs. 10–15.)

Aclisina striatula De Koninck, 1881, 'Faune du Calcaire Carbonifère de Belgique' pt. iii, Ann. Mus. Roy. Hist. Nat. Belg. vol. vi, p. 86 & pl. ix, figs. 57–58; and 1883, pt. iv, vol. viii, pl. xxxiii, figs. 41–42, & pl. xxxiv, figs. 49–51.

Murchisonia striatula De Koninck, 1843, 'Description des Animaux Fossiles du Terrain Carbonifère de Belgique' p. 415 & pl. xl, figs. 7 *a*–7 *b*.

Murchisonia subsulcata De Koninck, 1843, *op. cit.* p. 416 & pl. xxxviii, figs. 4 *a*–4 *c*.

Aclisoides (Murchisonia) striatula De Koninck, Donald, 1898, Q. J. G. S. vol. liv, p. 67 & pl. v, figs. 6–8.

Aclisoides striatula, var. *armstrongiana* Donald, 1898, *op. cit.* p. 68 & pl. v, fig. 10 [exclude fig. 9].

Rhabdospira selkirkii Donald, 1898, *op. cit.* p. 65 & pl. v, fig. 4.

Remarks. I have already stated the reason (*op. cit.* pp. 45, 46) why this species could not be placed in the genus *Aclisina*: namely, the presence of a sinus in the outer lip and a protoconch of different

[1] Amer. Journ. Sci. & Arts, vol. ii (1858) p. 259. See also F. B. Meek & A. H. Worthen, Geol. Surv. Ill. vol. v (1873) p. 596 & pl. xxix, figs. 6 *a*–6 *b*.

form. At that time I did not know of the existence of any of the types of De Koninck's earlier work ('Descr. Anim. Foss. Terr. Carb. Belg.' 1843), and founded my remarks on the type selected when he wrote his later work ('Faune Calc. Carb. Belg.' 1881 & 1883), which is in the Musée Royal d'Histoire Naturelle at Brussels, as well as on similar specimens from the same locality in that and other collections. I understood him to tell me that all his early types had gone to America; subsequently, however, I had occasion to visit the École des Mines, Paris, where through the courtesy of M. Douvillé I was shown some types which had been presented by De Koninck in 1846.[1] Among them were *Murchisonia striatula* (Pl. VI, figs. 10 & 11) and *M. subsulcata* (Pl. VI, fig. 13). At first sight they appeared to be distinct species as described, but a close study of them, as well as of a large series of both Belgian and British specimens, has convinced me that they are conspecific. Since De Koninck does not refer to *M. subsulcata* in his later work, he may have realized this, though he has not published it. In the Liége Museum I saw three individuals from Visé undoubtedly conspecific, two of which were marked *A. striatula* and the other *M. subsulcata*. The type specimens are more or less distorted by pressure. That of *M. subsulcata* is rather flattened, so that from one point of view the spiral angle appears greater than it must originally have been, and this defect is exaggerated in De Koninck's figures; the surface is also somewhat worn, therefore he describes it as having bands instead of threads and grooves. The two examples of *M. striatula* are compressed in such a manner as to make the whorls appear more angular; in one, consisting of the body and penultimate whorl, this is only slightly so, but in the other the distortion is greater, so that the sutures are rendered very oblique and the whorls still more angular; the ornamenting threads on both are well preserved. The specimen marked as the type of *Aclisina striatula* in the Brussels Museum is almost normal; but it is smaller, and the surface is much worn.

This species exhibits a certain amount of variation, both in form and in the number and strength of the ornamenting threads. In some shells the whorls are more exsert, as in two purchased from De Koninck by the British Museum (Natural History) G 19984, which are marked *M. striatula* in his own handwriting, in the specimen described as *Rhabdospira selkirkii*, and also in a small example from Hairmyres, Lanarkshire (Pl. VI, fig. 15). In the greater number of specimens, however, the earlier whorls are closely coiled and increase slowly, in such wise that they are lower and broader than the later whorls: thus these shells are somewhat convex in contour, and when immature have a greater spiral angle than the anterior portion viewed alone has. The holotype of *M. subsulcata* and many specimens from Settle have this compact form, (Pl. VI, fig. 13, & *op. cit.* pl. v, figs. 6 7), while the two types of

[1] Annuaire Géol. Univers. 1885, 'Musées & Collections Particulières, Paris, École des Mines, Coll. de Paléont.' p. 214.

M. striatula, which consist of the later whorls of larger shells, give the impression of having more slender spires (Pl. VI, figs. 10 & 11). Other individuals are intermediate, such as the Brussels type (Pl. VI, fig. 12) and some of the specimens from Strathavon, Lanarkshire.

The type example of *M. subsulcata* is remarkable for showing the sinus in the outer lip, while the other specimens with one exception only indicate it by the lines of growth. The sinus does not give rise to so distinct a band as in *Murchisonia, sensu stricto*, and is sometimes difficult to discern, being formed of from two to five threads similar to those ornamenting the rest of the surface. The position of the sinus is most evident on shells with a slightly worn surface. The majority of the specimens have fine threads intercalated between coarser ones, and two of the latter below the band are generally stronger than the others on the whorls of the spire.

I consider that the shell described by me as *Rhabdospira selkirkii* belongs to this species; it occurred as an external mould in the Main Lime at Braidwood, Carluke, and has unfortunately been destroyed by fire in the Hunter-Selkirk Collection, so that it is now only represented by wax impressions. It is the anterior portion of a large specimen; the whorls are high, and show numerous ornamenting threads. From the markings on the surface I was led to think that the lines of growth were but slightly sinuated, and that there was not a distinct sinus. As there is evidence of a breakage near the aperture, and these markings are only observed in that vicinity, they are probably adventitious. The shape of the shell and disposition of the ornamenting threads greatly resemble some of the Belgian examples of *A. striatula*, especially the least crushed one in the École des Mines, Paris.

The specimen designated as the variety *armstrongiana* (*op. cit.* p. 68 & pl. v, fig. 9) must be regarded as a distinct species, and that represented by fig. 10 as merely a flattened and worn example of the typical form.

Holotype. De Koninck did not select any one specimen as holotype. The two early types in the École des Mines, Paris, agree very nearly with his specific description; but the fragment (Pl. VI, fig. 11), consisting of two whorls alone, accords with the enlarged drawings, fig. 7 *b* of pl. xl, 'Anim. Foss. Terr. Carb. Belg.,' and fig. 58 of pl. ix, 'Faun. Calc. Carb. Belg.' It has a length of 10 millimetres, and its greatest width = 7 mm.

The other shell (Pl. VI, fig. 10), consisting of five whorls, does not accord with either of the figures of a complete shell given in these works. The length = 16 millimetres, and the greatest width of the penultimate whorl = 8·25 mm.

The small worn specimen (Pl. VI, fig. 12) in the Royal Brussels Museum, marked as the type in the later work, does not correspond with any figure, although it belongs to the species. It consists of eight whorls in a length of 9·5 millimetres, and has a width of 3·5 mm.

The holotype of *M. subsulcata* has eight whorls in a length of 18·5 millimetres; its greatest width=6·75 mm., and the depth of the sinus=about 2·5 mm.

I give new drawings of these shells in Pl. VI, figs. 10–13, which should be compared with the figures 4, 6, 7, 8, & 10, of pl. v, Q. J. G. S. vol. liv (1898), as well as with figs. 14 & 15, Pl. VI, of this paper.

Locality and horizon.—Visé, Assise vi.

This species has previously been stated to occur at Settle[1] in England: at Craigenglen in the Lower Limestone Series, and at Glencart, Dalry, in the Upper Limestone Series, in Scotland. Specimens from the English locality greatly resemble in size and character those from Visé, as do also two from Craigenglen. One of these last is in the Royal Scottish Museum, Edinburgh; the other belongs to Mr. J. Smith, and is rather larger and better preserved: it has eight whorls in a length of 17 millimetres, while the greatest width=6 mm. The examples from Glencart, like the other gasteropoda from that locality, are very small.

Mr. Robert Dunlop possesses the best series that I have seen: it consists of ten specimens which are for the most part large, with the surface wonderfully well preserved, showing the sinual band, lines of growth, and ornamenting threads very distinctly. The latter are especially fine and numerous above the band, while those forming the band itself vary in number and strength. In one of the biggest examples (Pl. VI, fig. 14) an old lip-margin is preserved, with a deep sinus: it is evidently not the final outer lip of the adult, as there are impressions of lines of growth on the matrix showing that the sinus had been filled up, and that part of the shell-structure had subsequently perished. These specimens were found a quarter of a mile east of Strathavon, in the Lower Limestone Series.

Besides the small specimen previously mentioned from the Lower Limestone Series of Hairmyres, Mr. John Smith's collection contains two minute examples from Brodlie, Dalry, and two others, also small, from Dernshaw, Stewarton (Ayrshire), from the Upper Limestone Series. He has also two immature shells from Poolvash (Isle of Man).

The late Mr. J. G. Goodchild found an external mould in the Yoredale beds on Widdale Fell, Mosedale (Yorkshire).

In Belgium this species occurs at Tournai, as well as at Visé. I possess two specimens from the former locality purchased from M. Piret, and there are also two in the British Museum (Natural History). Prof. L. G. de Koninck merely noted its existence at Visé.

Altogether I have examined about sixty specimens of this species, only two of which, both from Craigenglen, have the protoconch preserved.

[1] Most of the specimens from this locality are in the Sedgwick Museum, and were collected by Mr. Burrow; they are merely labelled 'Carb. Lst., Settle,' and the exact locality is not recorded.

ACLISOIDES ? ARMSTRONGIANA Donald.

Aclisoides striatula, var. *armstrongiana* Donald, 1898, Q. J. G. S. vol. liv, pars, p. 68 & pl. v, fig. 9 [exclude fig. 10].

Diagnosis.—Shell elongated, conical, composed of more than eight whorls. These are slightly angular a little below the middle, flat above, and convex below. The ornamentation consists of six threads on the lower two-thirds of the whorl, the three upper of which are the strongest and suggest a sinual band. Lines of growth unknown. Sutures deep. Aperture longer than wide; inner lip reflected on the body-whorl. Columella nearly straight. Base convex, slightly produced.

Remarks.—I formerly considered this a variety of *A. striatula* (De Koninck), but I now believe it to be a distinct species, and therefore give a fresh diagnosis. It is distinguished from *A. striatula* by its less convex contour, more angular whorls, and deeper sutures, as well as by the disposition, number, and relative strength of the ornamenting threads. I can only refer this species to *Aclisoides* with a query, as none of the specimens met with have the protoconch or lines of growth preserved. It is quite possible that the discovery of better examples may prove it to belong to *Aclisina*.

Holotype.—*Op. cit.* pl. v, fig. 9. Bennie Collection, Royal Scottish Museum, Edinburgh.

Dimensions.—Length = 10 millimetres; width = 3 mm.

Locality and horizon.—Law, Dalry, in the Lower Limestone Series. Besides the holotype there are two smaller specimens from this locality in the same collection, and Mr. J. Smith has two examples from Dykes, Kilbirnie, also from the Lower Limestone Series.

EXPLANATION OF PLATES V & VI.

PLATE V.

Fig. 1. *Aclisina pulchra* De Koninck. Holotype, × 3. Tournai. Brussels Museum. (See p. 68.)

Figs. 2 *a* & 2 *b*. *Aclisina pulchra* De Koninck. Fig. 2 *a*. Slightly flattened, × 3. Fig. 2 *b* Portion of fifth whorl, × 12. Tournai. Dorlodot Collection.

3 *a* & 3 *b*. *Aclisina venusta*, sp. nov. Fig. 3 *a* × 5. Fig. 3 *b* Body-whorl, × 9. Law, Dalry. Bennie Collection, Royal Scottish Museum, Edinburgh. (See p. 69.)

Fig. 4. *Aclisina faber*, sp. nov. Back view, × 7·5. (See p. 70.)

Figs. 5 *a*–5 *c*. *Aclisina faber*, sp. nov., juv. Fig. 5 *a*. Front view, × 22·5. Figs. 5 *b* & 5 *c*. Different views of the protoconch, × 26. High Smithston, Kilwinning. Collection of Mr. John Smith.

6 *a*–6 *c*. *Aclisina delicatula*, sp. nov. Fig. 6 *a*. Back view, × 10. Fig. 6 *b*. Aperture, × 15. Fig. 6 *c*. Protoconch, × 26. Longstaff Collection. (See p. 71.)

7 *a* & 7 *b*. *Aclisina micula*, sp. nov. Fig. 7 *a*. Back view, × 15. Fig. 7 *b*. Protoconch, × 26. High Smithston. Collection of Mr. John Smith. (See p. 71.)

Fig. 8. *Aclisina similis* Donald. Protoconch, × 26. High Smithston. Collection of Mr. John Smith. (See pp. 71–72.)

J.L., del.

Bemrose, Collo, Derby.

ACLISINA.

J. L., del.

Bemrose Collo, Derby

ACLISINA and ACLISOIDES.

Fig. 9. *Aclisina pusilla* Donald. Protoconch of the holotype, × 26. Law, Dalry. Collection of Mr. John Smith. (See p. 72.)

10. *Aclisina elongata* (Fleming). Holotype, × 14. Lauriston (Brankam Hall). Ure Collection, Royal Society, Edinburgh. (See p. 72.)

11. *Aclisina elongata* (Fleming). Front view of a remarkably well-preserved specimen, × 10. Crawfield Quarry, Beith. Young Collection, Kelvingrove Museum, Glasgow.

12. *Aclisina elongata* (Fleming). Side view of protoconch, × 26. Dykes, Kilbirnie. Collection of Mr. John Smith.

Figs 13 *a* & 13 *b*. *Aclisina elongata*, var. *cingulata* Donald. Fig. 13 *a* × 10. Fig. 13 *b*. Portion of whorl enlarged, × 15. Glencart. Young Collection, Kelvingrove Museum, Glasgow. (See p. 73.)

Fig. 14. *Aclisina elongata*, var. *cingulata* Donald. Front view of protoconch, × 26. Dykes, Kilbirnie. Collection of Mr. J. Smith.

15. *Aclisina elongata*, var. *varians* Donald. Back view of protoconch, × 26. Dykes, Kilbirnie. Collection of Mr. J. Smith. (See p. 73.)

Plate VI.

Fig. 1. *Aclisina subelongata*, sp. nov., × 10. Moss Mullock, Kilwinning. Collection of Mr. J. Smith. (See p. 74.)

2. *Aclisina elegantula* Donald. Protoconch, × 27. Law, Dalry. Bennie Collection, Royal Scottish Museum, Edinburgh. (See p. 74.)

3. *Aclisina striatissima* Donald. Front view, × 16. Law, Dalry. Longstaff Collection. (See p. 75.)

4. *Aclisina striatissima* Donald. Protoconch of another specimen, × 26. Law, Dalry. Longstaff Collection.

5. *Aclisina tenuistriata* Donald. Protoconch, × 26. High Smithston. Collection of Mr. J. Smith. (See p. 76.)

6. *Aclisina aciculata* Donald. Front view, × 26. Dykes, Kilbirnie, Collection of Mr. J. Smith. (See p. 77.)

7. ? *Aclisina multivolva*, sp. nov., × 10. Moss Mullock. Collection of Mr. J. Smith. (See p. 77.)

8. ? *Aclisina multivolva*, sp. nov., × 10. Glencart, Dalry. Young Collection, Kelvingrove Museum, Glasgow.

9. *Aclisina ashtonensis* (Bolton). Penultimate whorl of a specimen showing lines of growth, × 12. Ashton Vale Colliery. Bolton Collection, Bristol Museum. (See p. 78.)

10. *Aclisoides striatula* (De Koninck), × 3. Greatly contorted obliquely. Visé. One of the type specimens of *Murchisonia striatula* De Koninck, in the École des Mines, Paris. (See pp. 78–81.)

11. *Aclisoides striatula* (De Koninck). Back view of another type specimen, × 3. Visé. École des Mines, Paris.

12. *Aclisoides striatula* (De Koninck). Holotype of *Aclisina striatula* De Koninck, × 5. Visé. Musée d'Histoire Naturelle, Brussels.

13. *Aclisoides striatula* (De Koninck). Holotype of *Murchisonia subsulcata* De Koninck, × 3. Flattened by pressure. Visé. École des Mines, Paris.

14. *Aclisoides striatula* (De Koninck), × 3. Showing sinus in old lip-margin. Spiral angle greater than usual. Strathavon. Collection of Mr. R. Dunlop, Dunfermline.

15. *Aclisoides striatula* (De Koninck), × 10. Small specimen with whorls more exsert than usual. Hairmyres. Collection of Mr. R. Dunlop.

5. *The* Carboniferous Limestone *bordering the* Leicestershire Coalfield. By Leonard Miles Parsons, D.I.C., M.Sc.(Lond.), F.G.S. (Read March 14th, 1917.)

[Plates VII–XI.]

Contents.

I. Introduction.

The area containing eight inliers of Lower Carboniferous rocks with which this paper deals is situated north and east of Ashby-de-la-Zouch. These inliers of Avonian rocks lie within a radius of 6 miles from Ashby-de-la-Zouch, and the area forms a quadrant with the line Ashby Ticknall as the south-to-north radius, and the line from Ashby passing through Thringstone as the west-to-east radius.

The westernmost inliers, Ticknall and Calke, are in Derbyshire, as is also part of the Dimminsdale inlier. The Heath End stream which flows through the last inlier is there the county boundary. The eastern side of Dimminsdale and all of the remaining inliers, from Breedon to Grace Dieu inclusive, are situated in Leicestershire.

The Carboniferous Limestone of the area has been mentioned but briefly in the Memoirs of the Geological Survey, and the relations of the Lower Carboniferous to the Millstone Grit have not been definitely stated.

The original survey of the district was made by Edward Hull, and his results were published in 1860.[1] His map shows a ninth Carboniferous Limestone inlier situated north of Breedon-on-the-Hill, and south-east of Melbourne, but no description of it is given in the Memoir, and it is not shown in maps published more recently by the Geological Survey.

In the same Memoir (1860) a list of fossils obtained from Breedon and Breedon Cloud is given; but Hull considered the two Breedons to be alike stratigraphically, and the names of the fossils from the two places were put together in the same list, without any indication as to which Breedon yielded any particular specimen.

[1] 'The Geology of the Leicestershire Coalfield' Mem. Geol. Surv. 1860.

The Survey Memoir gives two diagrams of importance [pp. 15 & 17] in connexion with the present paper:—

(i) Sketch of strata seen in the quarry at Grace Dieu. The place is now so overgrown that the sequence and relation of the strata are obscured.
(ii) 'Section across Stanton Harold and Heath End,' showing the Millstone Grit conformable with the Shales below.

The district was re-surveyed by C. Fox-Strangways in 1898, and his results were published in the Memoir of 1905.[1] In this Memoir is published a list of fossils obtained from three of the inliers: namely, Ticknall, Breedon-on-the-Hill, and Breedon Cloud. The material from which this list was compiled is for the greater part in the collection at Repton School. In addition to the list of fossils, a few notes of a general character are given concerning the Carboniferous Limestone.

In a later Memoir[2] by the same author, the account of the Lower Carboniferous is much the same as that given in the 1905 Memoir, but at the end of the list of the fossils from Ticknall, Breedon, and Breedon Cloud [p. 15], occur the words: 'The above assemblage gives definite indications of the presence of the *Dibunophyllum* Zone.' Since 1907 nothing has been published concerning the palæontology and zoning of the Carboniferous Limestone of the district.

Two factors have made the study of the Carboniferous Limestone north of Ashby a matter of considerable difficulty: (1) The old lime-works at Ticknall and the exposures in Calke Park have presented unusual difficulty, as permission to examine them has always been refused. My own examination of this relatively small area has been delayed considerably, but I am pleased to say that all of the exposures have now been examined.

(2) The inliers farther east, which I have been at liberty to examine, thanks to the courtesy of Mr. J. G. Shields, of Islay Walton, are composed of almost barren dolomites. Breedon-on-the-Hill and Osgathorpe are particularly barren. Breedon Cloud is not much better in this respect, but I have received great help in dealing with the fauna of this inlier from Mr. R. Wood, of Melbourne, who has placed at my disposal the fine collection of specimens that he has gradually accumulated in the course of observations extending over many years.

As a result of correspondence with Mr. R. G. Carruthers, Mr. A. R. Horwood, and the late Dr. Arthur Vaughan, I began an examination of the area during the summer of 1912. Since then the work has proceeded slowly, on account of the difficulties encountered.

Although this paper deals more particularly with the faunal assemblages of the Carboniferous Limestone of the district, certain questions of petrological interest, such as dolomitization, have received attention.

[1] 'The Geology of the Country between Derby, Burton-on-Trent, Ashby-de-la-Zouch, & Loughborough' Mem. Geol. Surv. 1905.

[2] 'The Geology of the Leicestershire & South Derbyshire Coalfield' Mem. Geol. Surv. 1907.

In expressing my thanks to those geologists who have rendered me assistance, I must record my indebtedness to the late Dr. Arthur Vaughan, who examined my collection, identified several specimens, and encouraged me by helpful criticism and suggestions. Some months ago he urged me to publish my results at once, but unfortunately I was unable to do so, as I had not then examined all of the exposures in Calke Park. I have great pleasure in acknowledging the continual encouragement and valuable advice received from Prof. W. W. Watts, whose kind help has enabled me to give more serious attention to the examination of the Melbourne area than it was possible for me to do during the years 1912 and 1913.

I am grateful for criticism and advice received from Prof. C. G. Cullis and Dr. A. Morley Davies. To Mr. R. Wood, of Melbourne, I am indebted, not only for the use of his unique collection, but also for help and companionship in the field. Several photographs illustrating this paper are the work of Mr. G. S. Sweeting, and I have received considerable help in the petrological work from Mr. E. J. Tallin. To both of these gentlemen I offer my sincere thanks.

II. General Description of the Area.

The district being small and possessing relatively simple structural features, little need be said under this heading. The general succession of rocks dealt with is the following:—

(3) Millstone Grit.
(2) Shales.
(1) Carboniferous Limestone.

Apart from the outcrop of pre-Cambrian rocks in the neighbourhood of the village of Thringstone, the oldest formation exposed in the area defined above is the Carboniferous Limestone, which crops out in two well-defined series of inliers—a western series and an eastern series. The area is bounded by unconformable Permian and Trias on the north, and in other directions mainly by two pre-Triassic faults. One of these, known as the Thringstone Fault, extends from Charnwood in a north-westerly direction towards Repton and brings the Coal Measures down on the south; the other, which we may call the Breedon Fault, passes north-westwards from Charnwood, and then swings northwards skirting Barrow Hill, Breedon Cloud, Breedon-on-the-Hill, and King's Newton towards the Trent at Swarkestone. The throw of the Breedon Fault is probably considerable, as a boring through the Trias near Tonge village reaches Carboniferous Limestone after passing through nearly 300 feet of Keuper and about 9 feet of what is probably Millstone Grit. The Millstone Grit inside the area is variable in thickness, the Geological Survey estimating that it varies between 200 and 300 feet. Wherever the junction of Millstone Grit with the Shales below is seen, there is a conformable sequence. The lower beds of the former are always conglomeratic, but the higher portion consists of fine yellowish-white grit, which

is worked in one or two small quarries in the vicinity of Melbourne. The Shales, which may be looked upon as homotaxial with the Pendleside Beds, are always sandy for a few feet before they finally give place to the true Millstone Grit. Their thickness in the area is very small compared with that of the Pendleside Beds in other districts, a maximum of about 35 feet occurring in the western inlier of Ticknall; while farther east at Breedon Cloud, these shales are probably even thinner, and the boring at Tonge passed through no beds that can be referred to this formation. Thus, both the Millstone Grit and the Shales rapidly become attenuated in an easterly direction. The Carboniferous Limestone of the area has a total thickness of about 900 feet, of which some 850 feet are seen at Breedon-on-the-Hill, the remaining small thickness occurring at Ticknall, where the beds carry upwards the Breedon sequence. The base of the Carboniferous Limestone is not seen anywhere in the area, although a boring at Desford in the Whitwick district (9 miles south-east of the Thringstone Fault) has shown that about 20 feet of limestone there rests on pre-Cambrian rocks, a description of which has been given by Prof. W. W. Watts in the Geological Survey Memoir on the Leicestershire & South Derbyshire Coalfield.

The features of the Eastern and Western series of inliers may be summarized as follows:—

The Western Series, including Ticknall, Calke Park, and Dimminsdale, consist of earthy, dolomitic, and for the most part highly fossiliferous limestones, exposed along valleys and hollows by stream-erosion which has removed almost horizontal beds of Trias and Millstone Grit, showing a small thickness of limestone and ‘Pendleside’ Shales.

The Eastern Series of inliers, including Breedon-on-the Hill, Breedon Cloud, Barrow Hill, Osgathorpe, and Grace Dieu, are exposed by earth-movement which has tilted the Carboniferous Limestone along the Breedon Fault. The material itself is of a highly dolomitic nature and poorly fossiliferous. ‘Pendleside’ Shales are only once seen, and the Millstone Grit is never visible.

III. The Western Inliers.

In addition to their mode of exposure and the almost horizontal lie of the beds already noted, the strata exposed at Ticknall, Calke, and Dimminsdale have certain characters in common. In all cases fossiliferous and dolomitic limestones relatively poor in magnesia, and separated by thin shaly beds, pass upwards into yellow and grey dolomites having a percentage of magnesia approximating to that of theoretical dolomite. The lower impure and less dolomitic limestones yield an abundant fauna characteristic of a high horizon in the *Dibunophyllum* Zone. The dolomites which rest on them terminate the Carboniferous Limestone, and the Shales above are succeeded conformably by Millstone Grit.

The strike of the strata is approximately north and south; but the dip alters in amount and direction, owing to the occurrence of

small local faults and gentle rolls. Both Permian and Trias are unconformable with the Carboniferous at Ticknall, but the Trias alone is present at Calke.

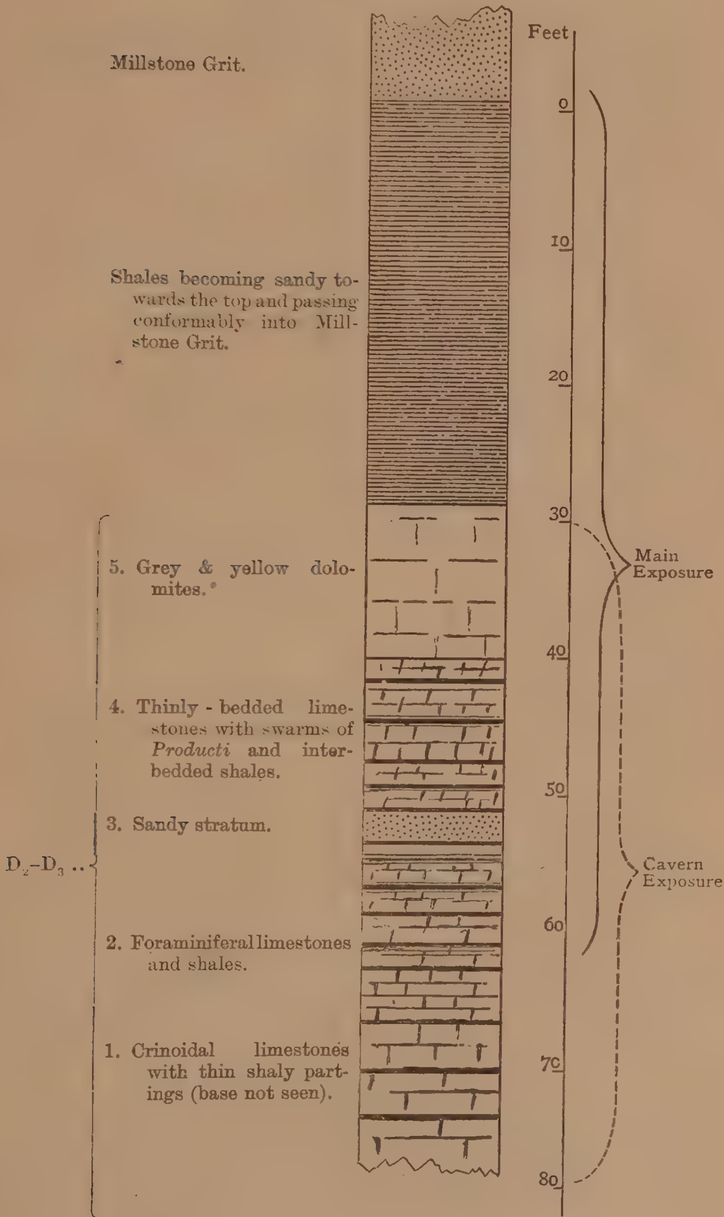
Patches of reddish marl seen resting directly upon limestone at Ticknall must be considered as Drift. The microscopic structure of the limestone immediately under this red material shows none of the zonal hæmatite arrangement characteristic of the dolomitized limestones seen to underlie the Trias at Breedon and Breedon Cloud. Flints obtained from this red material at Ticknall are used in the renovation of pathways in Calke Park. Remnants of Trias certainly occur on Millstone Grit at Ticknall, and in Calke Park south of the Abbey. At the extreme north-western edge of the Carboniferous outcrop at Ticknall a marl (referred by the Geological Survey to the Permian) oversteps the Millstone Grit and Pendleside Shales, and rests directly upon dolomitic limestone. This marl, which is covered by Trias farther westwards, is worked in a small brickyard. The exposures occurring in the western inliers are in general much overgrown, but the old lime-works at Ticknall present facilities for a study of the general sequence of strata and their faunal contents.

The Ticknall Inlier.

The road from Melbourne to Repton passes through the village of Ticknall, where exposures of Carboniferous rocks are seen on both sides of the road. Those on the northern side, near the brickyard mentioned above, are much less extensive and more overgrown than the more recently worked quarries on the southern side, though sufficient material may be examined to show that the beds on both sides are of the same lithological type and contain a similar fauna. The presence of water, which has filled up old workings, hinders examination on both sides of the road. The dip generally is towards the west, and its amount varies but is never very high, an average being about 8°.

Though most of the area on the southern side of the road consists of a rambling maze of overgrown exposures, disused tunnels, heaps of waste material, etc., there are two quarries in connexion where the sequence can be well seen. The larger of these, which we may call the Main Quarry, shows recently-worked limestones rich in *Productus* (4): this is underlain by limestones and shales (2–3), and overlain by dolomites (5), which are in turn followed by conformable 'Pendleside' Shales and Millstone Grit. This is the quarry that can be seen from the roadway leading into the village from Melbourne. Slightly farther to the south-east is the second quarry, the workings of which have been prolonged in the form of caverns; this may be called the Cavern Quarry. This shows a similar sequence from (2–5), but crinoidal limestones (1) below (2) are brought up by a small fault between the two quarries, and the upper part of (5) has been removed by denudation. The complete sequence of Carboniferous rocks seen at Ticknall is given in the section (fig. 1, p. 89) as follows:—

Fig. 1.—*Sequence of Lower Carboniferous strata exposed at Ticknall.*



The total thickness of limestone and dolomite seen at this locality is about 48 feet. As will be seen from the section, the 'Cavern' exposures exhibit beds lower than those at the base of the 'Main' exposure.

The strata observed at Ticknall are typical of the Western Series of inliers, and a few comments on the nature of the Ticknall beds may be given here.

The crinoidal limestones at the base of the Cavern exposure are mostly thin-bedded, contain a considerable amount of argillaceous matter, and are separated by thin bands of shale; the bulk of the rock consists of large unaltered crinoid-stems. Dolomite is absent, the very small amount of magnesium carbonate present not sufficing for the formation of definite rhombohedra. This point is discussed in a later section of the paper.

The fine-grained foraminiferal limestones succeeding the crinoid beds contain hardly any dolomite rhombohedra in their lower part, but a greater proportion in their upper. The bulk of the rock consists of impure argillaceous limestone, containing about 8 per cent. of impurities insoluble in acids. A certain amount of recrystallized calcite occurs in place of some original organic structures.

About 2 feet of a fine-grained sandy material containing *Productus* shells and a little dolomite succeed the foraminiferal limestone just described, indicating an unusually abrupt alteration in the conditions of sedimentation.

Above the sandy stratum come several feet of thinly-bedded '*Productus*' limestones with thin shaly partings. The proportion of magnesium carbonate is below 12 per cent., and rhombohedra of dolomite are rare.

Grey and yellow dolomites terminate the Carboniferous Limestone at this locality. So far as I am aware, there is in the Geological Survey Memoirs no description or even mention of these dolomites. The beds immediately underneath the shales of 'Pendleside' type in the Western inliers consist of about 10 feet of almost pure dolomite devoid of fossils. Partings of shale are not present, as in the lower beds seen here. In the lower part of the dolomite the higher proportion of limonite gives the body of the rock a yellow colour, but in the grey dolomite above the iron compounds present appear to be in the form of carbonate, which weathering to limonite on the exterior forms a brown crust, and this gives to the unbroken rock the appearance of a dark grit. In other respects the yellow and grey dolomites are very similar. No chert has been found in any of the beds exposed in the Western inliers.

Palæontology of the Ticknall Beds.

In compiling the faunal list my own collection has been the main source of information, but I have received the loan of specimens from Mr. R. Wood, of Melbourne, Dr. Turton, of Heanor, and Dr. F. L. Kitchin, of the Geological Survey. Mr. Vassall, of

Repton, kindly arranged for me to examine the School collection of specimens mostly collected some years ago; but, owing to illness at the time, I was unable to take advantage of his kindness. The list of species tabulated in the Geological Survey Memoir [1] was based upon this collection, and some of the names, particularly of corals, have been brought up to date.

Faunal List.

[c = common; cc = very common; r = rare; rr = very rare.]

D_2–D_3

Corals.

Zaphrentis enniskilleni Edwards & Haime. c.
Zaphrentis aff. *oystermouthensis* Vaughan. c.
Syringopora cf. *geniculata* Phillips. c.
Syringopora cf. *reticulata* Goldfuss. c.
Alveolites septosa (Fleming). rr.
Campophyllum derbiense Vaughan. r.
Caninia cf. *patula* Michelin. r.
Cyathophyllum sp. r.
Lithostrotion junceum (Fleming). cc.
Lithostrotion irregulare (Phillips). rr.
Koninckophyllum aff. *magnificum* (Thomson & Michelin). r.
Lonsdalia floriformis floriformis (Martin). rr.
Dibunophyllum muirheadi. c.
Small indeterminate Clisiophyllids. c.

Brachiopods.

Seminula ambigua (Sowerby). c.
Athyris planosulcata (Phillips). c.
Martinia glabra (Martin). r.
Martinia lineata (Martin). rr.
Spirifer bisulcatus Sowerby. c.
Spirifer duplicosta Phillips. r.
Spirifer integricosta Phillips. r.
Spirifer planicosta (M'Coy). c.
Spirifer striatus (Martin). r.
Orthotetes cf. *crenistria* (Phillips). r.
Schizophoria resupinata (Martin). r.
Productus antiquatus Sowerby. c.
Productus auritus. c.
Productus giganteus (Martin). cc.
Productus latissimus Sowerby. c.
Productus longispinus Sowerby. c.
Productus pugilis Phillips. c.
Productus scabriculus (Martin). r.
Productus semireticulatus (Martin). r.
Productus spinulosus Sowerby. r.
Chonetes cf. *hardrensis* Phillips. c.

The following genera and species of corals found in the *Lonsdalia* sub-zone of the Carboniferous Limestone of the Derbyshire area, have not been found:—

Lonsdalia duplicata (Martin).
Cyathophyllum regium Phillips.
Dibunophyllum matlockense Sibly.
Dibunophyllum derbiense Sibly.
Lithostrotion martini Edwards & Haime.
Lithostrotion aff. *m'coyanum* Edwards & Haime.
Lithostrotion flemingi M'Coy.
Michelinia glomerata M'Coy.
Aulophyllum sp.

The general faunal assemblage leaves no doubt that the fossiliferous beds of Ticknall are equivalent to the higher beds of the Carboniferous Limestone sequence of the Midland Province. It is probable that the Ticknall beds are of D_2–D_3 age.

[1] 'Leicestershire & South Derbyshire Coalfield' 1907

A feature of special interest is the occurrence of a *Caninia* related to *Caninia patula* of the South-Western Province. In the faunal list I have named this coral *Caninia* cf. *patula*, and a brief description of it is given in the palæontological notes; but, acting on the late Dr. Vaughan's advice, I am classifying, in a separate paper, the patulid Caninias under a new generic name. Attention was drawn to the position of the *patula* division by Dr. Vaughan in the paper on the Burrington-Combe sequence.[1] The 'cf. *Caninia cylindrica*' mentioned in the Geological Survey list possibly refers to this patulid form, the true *Caninia cylindrica* being absent from all parts of the district.

All of the Ticknall limestone-beds below the barren dolomite yield *Zaphrentis enniskilleni*, and it is highly probable that the crinoidal limestones at the base of the Cavern Quarry are roughly equivalent to the highest beds on the western side of Breedon-on-the-Hill, where strata consisting originally of highly encrinital limestones have been dolomitized.

In the limestones (2), foraminifera are plentiful, including *Endothyra*, *Valvulina*, and several other genera.[2] *Zaphrentis enniskilleni* and other corals, particularly *Lithostrotion junceum*, occur in these beds; but the brachiopod *Productus* does not occur in such numbers as it does in higher strata. The genus *Productus* occurs in all of the fossiliferous strata, including the sandy bed; but it is in the limestones (4) that the *Producti* occur in great numbers. The species massed together in this way are chiefly variants of the so-called '*Productus giganteus*' including such forms as *P. giganteus* proper, *P. auritus*, and latissimoid *Productus*, all of which are very abundant. Other fairly common species are *P. pugilis*, *P. concinnus*, *P. antiquatus*, and *P. longispinus*. *P.* cf. *semireticulatus* and *P. scabriculus* are comparatively rare. *Chonetes* cf. *hardrensis* is fairly abundant, but papilionaceous *Chonetes* are extremely rare.

The Calke Inlier.

A few small exposures of Carboniferous Limestone and 'Pendleside' Shales occur in Calke Park, a short distance south-east of Ticknall; but the passage of one formation into the other is not seen. The only exposures of the Limestone sequence are along the course of a small stream, which flows eastwards to join that flowing through Dimminsdale. Some small exposures of shale are seen on the eastern edge of the park, near the junction of the two streams.

The thickness of limestone seen is very small. At two localities the exposures display a thickness of several feet. One of these

[1] S. H. Reynolds & A. Vaughan, 'Faunal & Lithological Sequence in the Carboniferous Limestone Series (Avonian) of Burrington Combe (Somerset)' Q. J. G. S. vol. lxvii (1911) p. 374.

[2] E. Wilson, 'On the Occurrence of Foraminifera in the Carboniferous Limestone of Derbyshire' Midland Naturalist, vol. iii (1880) p. 221.

places (A in Pl. XI) corresponds to the position indicated by the words 'limestone with *productus*' on the 6-inch Map deposited by the late C. Fox-Strangways at the offices of the Geological Survey; while the other place (B) is the site of the 'old quarry' shown on the same map. At both places the limestone is argillaceous, but that at A is more dolomitic than that at B. The general dip of the beds seen in the park is about 6° a little south of east.

The beds of A are slightly higher than those at B. The microscopic characters of the limestone of A (see Pl. X, fig. 3) indicate a rock composed mainly of organic remains—corals, small brachiopods, and foraminifera. A fair amount of recrystallized calcite is present, and occasional rhombohedra of dolomite. These rhombohedra are quite idiomorphic and contain limonite, but there is no zonal arrangement of inclusions. The proportion of magnesium carbonate is about 12 per cent. Fossils are not particularly abundant, variants of *Productus giganteus*, such as *P. auritus* and *P. antiquatus*, being the characteristic brachiopods.

Corals are rare, and I was unable to find any specimens except *Lithostrotion junceum*. These beds are evidently the equivalent of the foraminiferal limestones found towards the bottom of the beds exposed in the Main Quarry at Ticknall. The immediately succeeding strata are obscured by vegetation, but some feet higher a yellow dolomite similar in grain to that of Ticknall occurs. Along the northern side of the stream the ground is much overgrown, and I found no evidence concerning the unconformity of the Millstone Grit shown on the Geological Survey map. At the present time the exposures show limestones alone, the Millstone Grit being visible only on higher ground farther north, and the intervening land is overgrown. The old quarries on the south exhibit grit only. It is to be regretted that the examination of the Calke exposures is a matter of great difficulty; and this fact, together with the overgrown nature of the ground, now makes it impossible to see the exact relation of the Millstone Grit to the underlying beds.

The Dimminsdale Inlier.

A little to the south-east of Calke Park the Carboniferous Limestone and succeeding Shales crop out in a north-and-south valley traversed by the largest stream in the district. The Limestone is shown in old workings that are now flooded to the level of the upper dolomite, the limestones below being inaccessible. About 35 feet of shales are seen, conformable with the limestone below, and passing up gradually and conformably into Millstone Grit. The gradual passage and conformity are strikingly exhibited at a place (x on the map, Pl. XI) east of the stream, and overlooking one of the flooded quarries. Here the ground has fallen in, showing the rock facing eastwards, northwards, and westwards in turn.

The lower beds wholly composed of shale become interbedded with thin sandy layers towards the top, and these finally assume the pebbly character of the lowest part of the Millstone Grit. The dip of the beds is here about 4° to the south-east.

IV. The Eastern Inliers.

If we define the Eastern series of inliers as those occurring against the Breedon Fault, two small inliers—one at King's Newton north of Melbourne, where 'Pendleside' Shales are tilted against the Breedon Fault, and the other at Grace Dieu near Charnwood—must be included with the larger masses of Breedon Cloud, etc., although they more nearly resemble the rocks of the Western inliers of Ticknall, etc. The remaining inliers, from Breedon-on-the-Hill to Osgathorpe, possess many features in common, such as high inclination, the dense yellow dolomitic character of the strata, and, despite their relative barrenness, the presence of a fauna indicating stratigraphical horizons in the *Dibunophyllum* Zone.

Breedon-on-the-Hill.

This hill, which forms a landmark for many miles round, is made up of moderately thick-bedded dolomites, with some thinner beds in places. No interbedded shaly partings are seen, and the unconformable cover of the Trias conceals any 'Pendleside' Shales that may exist west of the hill. The strike is constant—about N. 20° E. to S. 20° W., while the angle of dip varies but slightly, averaging about 46° westwards. Slight flexures occur in the middle part of the sequence, but no faulting is apparent, the inlier differing remarkably in this respect from Breedon Cloud. The thickness of Carboniferous Limestone at Breedon-on-the-Hill is about 850 feet—a figure considerably greater than the 500 feet mentioned in the Geological Survey Memoir, which, however, does not make it clear whether Breedon-on-the-Hill or Breedon Cloud is meant.[1] The estimate of 850 feet is based upon measurements in the field guided by faunal evidence, and is confirmed by observations at Breedon Cloud. The great quarry-face at the southern end of the hill extends at right angles to the strike, and thus affords an excellent section. The beds exposed along this face constitute roughly two-thirds of the total thickness of the strata forming the inlier—the higher beds being covered with grass, except those at the very top of the sequence which are to be seen along the western side of the hill.

The whole of the rock exposed consists of dolomites, variable both in chemical composition and in mineralogical structure. A detailed subdivision of the beds, based upon either lithological or palæontological evidence, has not been found possible; but the sequence may be considered broadly to consist of four parts the exact boundaries of which are not very definite. Commencing at

[1] 'The Geology of the Country between Derby, Burton-on-Trent, Ashby-de-la-Zouch, & Loughborough' Mem. Geol. Surv. 1905, p. 18—Sheet No. 141.

the western side of the hill and working eastwards, we see that the main subdivisions are as follows, in descending order:—

D_2–D_3	4. Pink and red dolomite. 3. Yellow dolomites with some chert.
D_1 …	2. Thickly-bedded yellow dolomites with no chert, but yielding *Productus humerosus*. 1. Yellow dolomites and dolomitic limestones yielding *Lithostrotion irregulare*, Cyathophyllid corals of the *C. murchisoni* type, etc. (Base not seen.)

Total thickness = about 850 feet.

Since the exact boundaries of these subdivisions are not clearly seen, I prefer not to assign definite thicknesses to them; but the D_1 portion of the sequence (1 and 2) probably exceeds 500 feet. The total thickness, which is here greater than that at any other inlier north of the Leicestershire Coalfield, is such that, apart from palæontological evidence, it is justifiable to suppose that the lower beds on the eastern side of the hill must represent some portion of the D_1 limestone of the main Midland area.[1] A special point to be noted in this connexion is the entire absence of igneous material on the horizon of the 'toadstones' of Derbyshire. As the lower portion of the Breedon-Hill limestone is of D_1 age, it must be concluded that the area under consideration was beyond the south-eastern limit of the vulcanicity associated with the Carboniferous Limestone of the Pennine Chain. Dr. H. H. Bemrose in his paper on 'The Toadstones of Derbyshire,' refers to the thinning-out of the igneous material in an easterly direction, and draws attention to the absence of the 'upper toadstone' at Crich, only a few miles east of Matlock.[2]

Palæontology of Breedon-on-the-Hill.

The comparatively barren nature of the whole of the beds exposed at Breedon is indicated by the fact that hitherto but two species: namely, *Productus humerosus* and *Syringothyris (?) cuspidata*, have been quoted from this inlier; however, after a prolonged search, in which every available rock-face was examined, I have obtained sufficient specimens of corals and brachiopods to fix the horizon of the uppermost beds with certainty, and to leave little doubt that the lowest beds belong to the D_1 sub-zone.

Faunal List.

[Subdivisions indicated by numerals corresponding to those in the succession tabulated above.]

Upper Beds on the western side of the hill.

=(4) & part of (3).	*Zaphrentis* sp. (? *enniskilleni* Edwards & Haime). r. *Beaumontia egertoni* Edwards & Haime. r. *Lithostrotion* sp. r. *Diphyphyllum* aff. *concinnum* Lonsdale. r. *Spirifer planicosta* M'Coy. r. *Productus antiquatus* Sowerby. r.

[1] See Prof. T. F. Sibly's paper, Q. J. G. S. vol. lxiv (1908) p. 38.
[2] *Ibid.* vol. lxiii (1907) p. 266.

'*Humerosus*' Beds.

=(2). { *Syringopora* sp. r.
Pugnax pugnus (Martin). r.
Productus humerosus Sowerby. c.
Productus sp. r.

Lower Beds on the eastern side of the hill.

=(1). { *Syringopora* cf. *reticutata* Goldfuss. r.
Syringopora sp. r.
Michelinia? r.
Lithostrotion irregulare (Phillips). r.
Cyathophyllum aff. *murchisoni* Edwards & Haime. c.
Indeterminate corals, apparently of Cyathophyllid & Koninckophyllid types.

Beaumontia egertoni, *Spirifer planicosta*, and *Productus antiquatus* obtained from the western side of the hill, indicate that these beds (4) are correctly referred to the D_2 sub-zone, while the presence of *Zaphrentis* suggests that the horizon is the same as that of the fossiliferous beds of Ticknall. These strata consisted originally of highly encrinital material, and I conclude that they are the eastern extension of the crinoidal limestones seen in the western inliers. The dolomites with chert (3) are mostly hidden, as the quarries do not extend far enough westwards to break into them. Hence a thorough examination is impossible; but there is no reason to doubt that they are the same as the dolomites with chert seen at Breedon Cloud, where an undoubted D_2 fauna is obtained from them.

The yellow dolomites (2) with *Productus humerosus* yield that species in fair numbers, and it is supposed that these beds are the local equivalent of the Caldon-Low facies occurring near Waterhouses in the south-western part of the Midland area.[1] As at Caldon Low, *Syringopora* is the only coral found in these beds; but, on the other hand, *Pugnax pugnus*, a brachiopod that is not mentioned as being found in the Caldon-Low beds, occurs sparingly at Breedon, and *Daviesiella* aff. *comoides* does not appear to be associated with *Productus humerosus*. Prof. Sibly refers the Caldon-Low beds to the D_1 sub-zone, and the equivalent beds at Breedon-on-the-Hill are also referable to the same sub-zone, for they underlie a considerable thickness of cherty dolomites which are the local representatives of the cherty limestones of the D_2 sub-zone in the Midland area. The Caldon-Low facies has been observed only at the south-western extremity of the Midland area; and, if we consider the Carboniferous Limestone outcrops north of Ashby as a south-eastward extension of that area, it is interesting to note that the same specialized *Productus-humerosus* beds occur also at the extreme south-eastern corner of the Province.

The dolomites (1) below the '*humerosus*' beds, and forming the eastern side of the hill, are rather thickly-bedded and almost barren. Where the rock is not being worked it weathers with a grey outer

[1] T. F. Sibly, Q. J. G. S. vol. lxiv (1908) p. 44.

skin, which sometimes reveals impressions of coral. These impressions are mere surface-markings which are mostly indeterminate, and although coral structures exist in the rock, they too are so indistinct that sections are generally of even less value than the surface-markings. Undoubted specimens of *Cyathophyllum* aff. *murchisoni* occur in the rock; but the massive bedding and hardness of the dolomite make it almost impossible to extract them. Other surface-impressions indicate the presence of large single corals having a complex tabulate area, but it is impossible to refer them definitely to *Dibunophyllum* or any other genus.

Good specimens of *Lithostrotion irregulare* have been found, and this suggests that the eastern beds are not lower than D_1, a point supported by the total thickness of rock in the inlier, and by other evidence.

Syringopora occurs particularly in certain beds at the extreme eastern end, where masses of shells resembling papilionaceous *Chonetes* are also found; but a specific determination of these is not possible.

Breedon Cloud.

A distance of three-quarters of a mile separates the two Breedons. The quarry-face of the Cloud works extends for a length of about 500 yards, and is very often parallel to the strike: consequently the section is not so useful as that at Breedon-on-the-Hill.

The Carboniferous Limestone sequence at Breedon Cloud is as follows:—

D_4 D_3.	3. Thinly-bedded red dolomites with very thin shaly partings.
	2. Yellow dolomites, apparently of 'contemporaneous' origin, and containing a variable quantity of chert.
Part of D_1.	1. Yellow dolomites yielding *Productus humerosus*, but containing no chert.
	(Thickness unknown.)

On account of the amount of material removed by quarrying operations and the presence of many heaps of refuse, etc., an accurate statement can hardly be made concerning the actual thickness of the subdivisions. A few points concerning the divisions enumerated above may be noted here.

The lower, relatively barren, yellow dolomites yielding *Productus humerosus*, *Cyrtina septosa*, and *Pugnax pugnus* are best seen at the extreme northern end of the works, where faulting has produced a certain amount of lateral displacement. The positions where *Pr. humerosus* was obtained are indicated on the plan (fig. 2, p. 98) by the letter H.

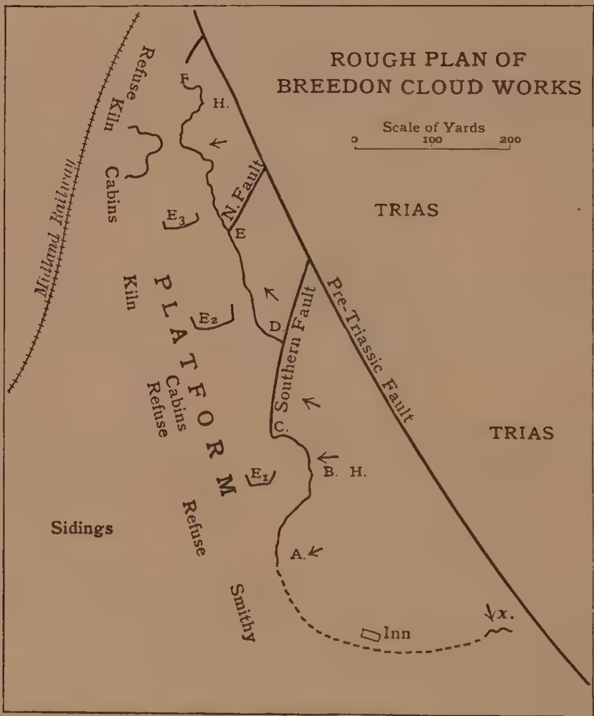
These beds are evidently equivalent to the corresponding *humerosus* dolomites at Breedon-on-the-Hill. At one other point towards the southern end of the inlier I obtained the same species of *Productus* at the top of the hill, a little distance east of the large amphitheatral quarry marked B on the plan. In no part of these beds was any chert found.

The succeeding yellow dolomites form the bulk of the exposed

part of the inlier, and yield a fauna characteristic of horizons that may be conveniently expressed by the formula D_2–D_3. Chert occurs somewhat sparingly, but is seen easily *in situ* in the various excavations (marked E_1, etc. on the plan) made in the platform that constitutes the floor of the main quarry.

The beds of this subdivision of the sequence are repeated by reversed faulting parallel with the strike. The faults responsible for this repetition are indicated on the plan at C and E.

Fig. 2.



The dip of the strata varies in degree from 48° to 60°, while the direction varies from directly south at the southern end of the hill to north-west near the position D half-way towards the northern end of the works. Breedon Cloud appears to be the remnant of a faulted dome, the eastern portion being thrown down by the pre-Triassic Breedon Fault.

Jointing is common, and in many places the direction of the dip is disguised, particularly in that part of the quarry that lies immediately north of the southern fault. There are many pockets filled with loose 'dolomitic sand' derived from the disintegration of the yellow dolomite, or from the thin overlying red dolomites.

Overlying the yellow dolomites are a few feet of thinly-bedded

red dolomites which have yielded *Zaphrentis enniskilleni* and *Diphyphyllum* aff. *concinnum*. Their faunal contents are generally similar to that of the red dolomites at the top of the sequence of Breedon-on-the-Hill. The origin of their dolomitization is discussed in a later section of this paper. One or two thin bands of shale interbedded with these red dolomites are also stained a dark red.

Palæontology of Breedon Cloud.

The exposed portion of Breedon-on-the-Hill consists of relatively barren D_1 beds; but at Breedon Cloud the exposures consist almost wholly of beds yielding a D_2–D_3 fauna. At the latter locality, however, the thickness of the material capable of being examined is much reduced, on account of the workings being generally parallel with the strike.

Faunal List.

D_2—D_3.

Sub-division 3 of table (p. 97).

Corals.

- *Zaphrentis* aff. *enniskilleni* Edwards & Haime. r.
- *Diphyphyllum concinnum* Lonsdale. c.
- *Diphyphyllum* near *concinnum* Lonsdale. Large form.

Brachiopods:

- *Spirifer planicosta* (M'Coy).
- *Productus* sp.

Sub-division 2 of table (p. 97).

Corals.

- *Beaumontia egertoni* Edwards & Haime. c.
- *Syringopora* cf. *reticulata* Goldfuss. c.
- *Syringopora* cf. *geniculata* Phillips. c.
- *Alveolites* sp. rr.
- *Campophyllum derbiense* Vaughan. c.
- *Cyathophyllum* sp. r.
- *Diphyphyllum lateseptatum* M'Coy. cc.
- *Diphyphyllum concinnum* Lonsdale. c.
- *Diphyphyllum* near *concinnum* Lonsdale, large form. r.
- *Lithostrotion irregulare* (Phillips). r.
- *Lithostrotion (Petalaxis) portlocki* Edwards & Haime. r.

Brachiopods.

- *Dielasma hastata* Sowerby. r.
- *Athyris expansa* (Phillips). c.
- *Martinia glabra* (Martin). c.
- *Martinia lineata* (Martin). r.
- *Martinia ovalis* (Phillips). r.
- *Spirifer bisulcatus* Sowerby. c.
- *Spirifer duplicosta* Phillips. r.
- *Spirifer planicosta* (M'Coy). c.
- *Spirifer trigonalis* (Martin). r.
- *Pugnax acuminatus* (Martin). r.
- *Leptæna analoga* (Phillips). c.
- *Orthotetes* cf. *crenistria* (Phillips). r.
- *Schizophoria resupinata* (Martin). r.
- *Pustula punctata* (Phillips). r.
- *Pustula pustulosa* (Phillips). r.
- *Productus giganteus* Martin. c.
- *Productus antiquatus* Sowerby. c.
- *Productus auritus*. c.
- *Productus latissimus* Sowerby. c.
- *Productus semireticulatus* (Martin). r.
- *Productus plicatilis* (Sowerby). r.
- *Productus undatus* Defrance. r.
- *Productus striatus* (Fischer). r.
- *Productus scabriculus* (Martin). r.
- *Orbiculoidea* cf. *craigi* Davidson. r.

D_1.

Sub-division 1 of table.

- *Productus humerosus* Sowerby.
- *Cyrtina septosa* (Phillips).
- *Pugnax pugnus* (Martin).

The palæontological material available is very poor, both in quantity and in state of preservation, compared with that usually obtained from normal undolomitized limestones of the *Lonsdalia* sub-zone. The compilation of the faunal list has only been possible through the kind co-operation of Mr. R. Wood, whose collection and help have always been at my disposal.

Coral structures have been preserved by dolomitic replacement, but all brachiopods occur as dolomite casts. Large single corals are usually represented by imperfect specimens of which the internal tabulate area has been removed; hence definite genera cannot be identified, though several may be present. In these circumstances it seems better not to make any statement with reference to genera or species that appear to be absent.

Barrow Hill.

South-south-east of Breedon Cloud, and at a distance of less than a mile from it, a small exposure of dolomite occurs in a disused quarry. Formerly the rock was worked for lime, but the place is now rather overgrown. The quarry faces all directions in turn. The beds on the northern side dip north-eastwards, but at the southern end the dip is south-westward on account of a fault. The rock consists of a dense yellow dolomite very similar to the denser, poorly idiomorphic, and purer dolomite of Breedon-on-the-Hill and Breedon Cloud. No deep-red hæmatite inclusions are present, although particles of insoluble matter or unaltered calcite give a cloudy appearance to the crystals. A little limonite is present. So far as I am aware, no fossils have been recorded from this inlier. Most specimens observed or collected by me were in a bad state of preservation, but the following may be quoted:—

Cyathophyllum (? regium).
Lithostrotion irregulare (Phillips).
Spirifer bisulcatus Sowerby.
Athyris sp.
Pugnax pugnus (Martin).
Productus sp.

Osgathorpe.

Very small exposures occur on both sides of the stream and road. Only a few feet of dense yellow dolomite exhibiting slight flexures are seen, and I was unable to obtain any fossils.

Grace Dieu.

The southernmost inlier of the district is situated quite close to Charnwood Forest, and about $2\frac{1}{4}$ miles south-east of Breedon Cloud. The exposures are very small and particularly barren. About 24 feet of dark impure limestones, quite unlike the Breedon yellow dolomite, somewhat thinly bedded and separated by thin bands of shale, constitute all that is to be seen. Numerous pockets in the limestone are filled with a brownish marl. The dip is about 10° northwards, and the limestone is faulted against the pre-Cambrian on the south. The only fossil that I obtained was a

Spirifer of doubtful species. Some time ago Prof. E. J. Garwood found a species of *Productus*, which he informed me was sufficient to fix the horizon as being fairly high up in the *Dibunophyllum* Zone, but unfortunately the specimen has been mislaid. It has been considered that the beds at Grace Dieu represent a higher horizon than that of any part of Breedon Cloud; but this cannot be the case, since the beds at the latter place range from the top of the '*humerosus*' facies in D_1 to the 'Pendleside' Shales.

V. Comparison of the Carboniferous Limestone of the Area with that of the Main District (Derbyshire and North Staffordshire) of the Midland Province.

A perusal of the lists of fossils tabulated in this paper, and those given in Prof. T. F. Sibly's paper on 'The Faunal Succession in the Carboniferous Limestone of the Midland Area,'[1] will show that, as one might expect, the Carboniferous Limestone north of the Leicestershire Coalfield is an eastern extension of the Midland Province. In other words, the faunal sequence exhibited in the inliers described above is essentially Midland in type.

A comparison of the Midland faunal succession with that of other Provinces is given in Prof. Sibly's paper and need not be repeated here. I propose only to comment on the relation of the Leicestershire area to that investigated by Prof. Sibly. In neither area is the base of the limestone seen.

1. D_1, the sub-zone of *Dibunophyllum* θ.

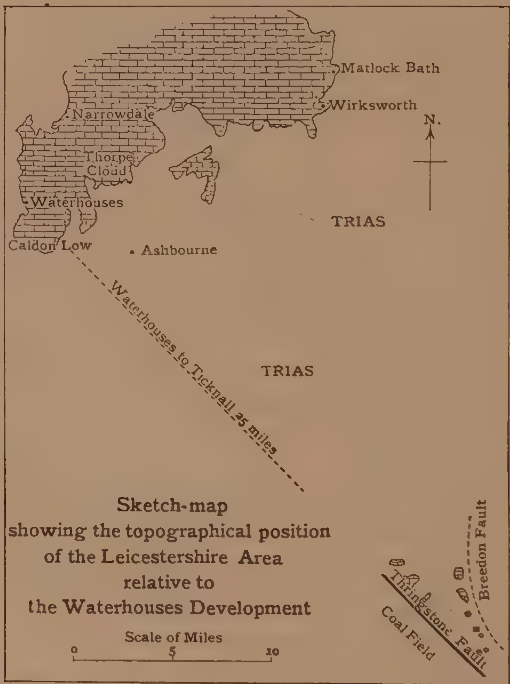
The upper limit of the sub-zone occurs a little above the Upper Toadstone in Derbyshire, but is indistinct in Leicestershire. The development in the south-western part of the main area of an abnormal facies known as the 'Caldon-Low Facies,' finds its parallel at Breedon and Breedon Cloud, and I consider this portion to be the highest part of D_1 definitely recognizable in the Leicestershire area. Its similarity to the corresponding beds at Caldon Low has already been noted in the description of the Eastern inliers. The remaining portion of the sub-zone below the *Productus-humerosus* beds must represent a corresponding thickness of the same sub-zone in Derbyshire. The fact that simple Dibunophyllids have not been found at Breedon can hardly be considered of value, as dolomitization has rendered it very difficult to identify such corals as do occur. Even the Derbyshire normal limestones are poorly fossiliferous, and *Dibunophyllum* occurs there but rarely in the lower portions of D_1. The typical form of *Productus giganteus* does not occur in this sub-zone in either district, but *Productus* aff. *giganteus* does occur.

[1] Q. J. G. S. vol. lxiv (1908) pp. 42 *et seqq.*

2. D_2, the sub-zone of *Lonsdalia floriformis.*

The following characters of the Leicestershire fauna illustrate general similarities of this sub-zone in the two districts:—The presence of *Campophyllum derbiense*, *Cyathophyllum regium*, *Lithostrotion irregulare*, *L. portlocki*, Zaphrentids in the uppermost beds, the great number of variants of *Productus giganteus*,

Fig. 3.



Sketch-map showing the topographical position of the Leicestershire Area relative to the Waterhouses Development

the occurrence of scabriculate and punctate *Producti* besides representatives of the *Martinia* group (particularly *M. glabra*), and the occurrence of *Spirifer bisulcatus* and *Spirifer planicosta*. In the following respects the fauna in Leicestershire differs from that of Derbyshire:—*Lithostrotion junceum* occurs in Leicestershire only in the upper beds as at Ticknall, and other species such as *L. martini*, *L.* aff. *m'coyanum*, and *L. flemingi* are apparently absent. *Dibunophylla* of an advanced type are not commonly found: *D. matlockense*, common in Derbyshire, being unrecorded from any of the inliers that I have described. *D. derbiense* is also absent, but *D. muirheadi*, a species that does not figure in Prof. Sibly's faunal lists, is of limited occurrence at Ticknall. In comparing the coral faunas of the two districts due allowance

must be made for the difficulty experienced in obtaining reliable specimens from the dolomites; but, even if this allowance be made, the coral fauna of the *Lonsdalia* sub-zone cannot be described as rich. The brachiopod fauna of D_2 in the two districts appears to be very similar; but some species, such as *Orthotetes* cf. *crenistria*, and papilionaceous *Chonetes*, are rarer in the Leicestershire district than they are in the other. Prof. Sibly distinguished certain variations in the faunal facies of the *Lonsdalia* sub-zone in the Derbyshire district—a general typical facies developed on the eastern side of the region, and a more or less local south-western facies with a poor coral fauna. The typical eastern facies includes *Lonsdalia floriformis*, *Lithostrotion junceum*, *Alveolites septosa*, and certain Clisiophyllids, none of which is present in the south-western facies. In the typical development, moreover, the brachiopods do not predominate over the coral fauna. In the south-western area near Waterhouses, the brachiopod fauna is richer than the coral fauna, and the species of *Lonsdalia*, *Lithostrotion*, and *Alveolites* mentioned above are absent, as are the Clisiophyllids *Histiophyllum*, *Rhodophyllum*, etc.

Both corals and brachiopods in the Leicestershire fauna show that it is with the Derbyshire south-western facies that correspondence is closest. Thus, in the Leicestershire area, *Alveolites septosa* has been found only at Ticknall, and there it is extremely rare; of *Lonsdalia floriformis* only one specimen has been found at Ticknall, and it is absent from other localities; *Lithostrotion junceum* occurs at Ticknall only, and there in beds that are at the top of the Leicestershire D_2–D_1 sequence. *Histiophyllum*, etc., probably do not occur, although the imperfect condition of coral specimens must be borne in mind.

With regard to the evidence available from brachiopods, the beds at Breedon Cloud certainly yield more of these than of corals. Not only, therefore, does D_1 (especially the *humerosus* beds) of the Leicestershire area resemble in facies that developed in the south-western part of the area examined by Prof. Sibly, but the resemblance is also strikingly marked in the sub-zone of D_2.

3. D_3, the sub-zone of *Cyathaxonia rushiana*.

In Leicestershire no typical development of the D_3 sub-zone exists, and *Cyathaxonia* itself has not been recorded from the area.

In the absence of the index fossil, the abundance of species common to D_2 and D_3 suggests that the beds yielding this fauna should be designated by the symbol D_2–D_3.

A Comparison of Lithological Features.

The chief lithological differences and similarities of the Midland sequence and that of Leicestershire may be shown conveniently in tabular form:—

	Main Midland Area.		Leicestershire.
	Typical Eastern District.	South-Western District.	
D_3. *Cyathaxonia rushiana.*	Limestone and black shales. Thinly-bedded dark limestones and shales with chert.	Limestones and shales. Chert in the limestones.	No typical development.
D_2. *Lonsdalia floriformis.*	Mainly thinly-bedded limestones with chert. Thickly-bedded white limestones in the lower part.	Variable limestones, dark shaly partings, and some chert.	Thinly-bedded dolomites succeeding moderately thick beds of yellow dolomite with a variable quantity of chert. } D_2–D_3.
D_3. *Dibunophyllum θ.*	Upper Toadstone. Thin dark limestones. Thickly-bedded white limestones. Lower Toadstone. Massive white limestone.	Massive white or grey limestones poorly fossiliferous.	Fairly thickly-bedded yellow dolomites. No igneous material.

VI. The Origin of the Dolomites.

The dolomites of the Leicestershire area exhibit characters indicating two distinct sources of origin which are believed to be referable to (1) the influence of salts in waters of pre-Triassic age, probably in the Carboniferous Sea itself, upon rocks that were deposited as normal organic limestones; and (2) the influence of waters associated with the Trias upon beds which were seemingly crinoidal limestones previously undolomitized.

The dense yellow dolomites forming the bulk of the sequence at Breedon, Breedon Cloud, etc.

The greater portion of the dolomites of the eastern inliers is composed of yellow material, the chemical composition of which does not differ greatly from that of a pure dolomite. Analyses of typical specimens from Breedon yield the following average percentages:—

Calcium carbonate	58·2
Magnesium carbonate	39·6
Iron compounds	1·5
Insoluble residue	0·7
	100·0

The amount of free calcite is always small, as shown by slides stained with Lemberg's solution. These dolomites are mostly of minutely crystalline texture, microscopic slides showing more or less idiomorphic rhombohedra, the outlines of which are seen more clearly under a high power (see Pl. X, fig. 5).

Limonite is present interstitially, but there are no zonal inclusions of hæmatite characteristic of the red dolomites described below.

Organic structures have been replaced by dolomite, or occur as dolomitic casts: and it is probable that many fossil structures have been obliterated altogether. The dolomitization of these beds appears to be so complete, that examination of the fossils and their matrix shows no 'selective' dolomitization.

The yellow and grey dolomites of Ticknall are very similar in mineralogical structure and chemical composition to the massive dolomites of the eastern inliers, but those at Ticknall are coarser in grain and quite barren of fossils (see Pl. X, figs. 1 & 2).

In all of these rocks there is a general absence of those features which usually indicate that the dolomitization is due to the influence of waters of a post-Carboniferous date, and field evidence appears to support the view that these dolomites are of the kind described as 'contemporaneous' by some authors. They occur in definite beds, do not pass laterally into unaltered limestone, and their conversion into dolomite does not appear to be due to faulting.

The thinly-bedded red dolomites of Breedon and Breedon Cloud.

Only in the uppermost beds of Breedon-on-the-Hill, and of Breedon Cloud is there evidence of dolomitization due to the influence of the Trias.

The rock is pink or red, and the dolomitization is variable in any particular stratum. The amount of hæmatite sometimes exceeds 5 per cent. Microscopic sections show relatively large idiomorphic crystals, with zonal inclusions of hæmatite, and having an almost clear outer zone (see Pl. X, fig. 4).

The only organic structures of common occurrence are crinoid stems, which remain mostly in an undolomitized condition. Here we note 'selective' dolomitization, in which the matrix is dolomitized while echinoderm structures remain unaltered. In no case have I found selective dolomitization, in which the rhombohedra have developed in organic structures and not in the matrix, as is the case in some vein-dolomites of other localities. But the characteristic zonal hæmatite inclusions which are always present, and the patchy nature of the dolomitization, leave little doubt that these red dolomites may be considered to be of 'subsequent' origin.

VII. Summary of Conclusions.

In the district immediately north of the Leicestershire Coalfield:—

1. There is a complete conformable sequence from the Carboniferous Limestone to the Millstone Grit inclusive, although the thickness of the beds of Pendleside aspect is small compared with that of the same formation in other districts.

2. The base of the Carboniferous Limestone is not seen, but borings have proved that it rests on pre-Cambrian rocks at Desford, in the neighbourhood of Charnwood Forest.

3. The total thickness of Carboniferous Limestone seen is about 900 feet, all of it included in the *Dibunophyllum* Zone, the subzones recognizable being D_1, D_2, and possibly part of D_3.

4. Faunal characters indicate that the Carboniferous Limestone belongs to the Midland Province, but that it more closely resembles the non-typical development occurring in the south-western part of the Main Area of that province. The development is not the normal facies characteristic of the greater part of Derbyshire, and the various inliers described in this paper must be regarded as a south-eastern extension of the Caldon-Low facies so far as D_1 is concerned, and of the Waterhouses facies as regards the portion above D_1.

5. The normal limestones of the Midland Province are represented by dolomites due, probably, to shallow-water conditions of deposit.

6. The great mass of dolomite is of contemporaneous origin, only certain beds of a high horizon, D_2–D_3, being dolomitized subsequently.

VIII. Palæontological Notes.

It was my intention originally to give a detailed account of certain new species, chiefly of *Caninia*, *Zaphrentis*, and *Syringopora*, in connexion with the present paper; but it will be better to deal with the matter separately. A few notes, however, are added to explain one or two items occurring in the faunal lists.

The Ticknall exposures yield a variety of Zaphrentids which include forms that resemble *Zaphrentis oystermouthensis* Vaughan, found associated with *Z. enniskilleni* in beds of D_2–D_3 age in the Gower district of the South-Western Province.[1] In the Ticknall specimens, the following characters indicate the similarity. The calyx is deep. The fossula is on the concave side, and extends more than half-way across the diameter of the coral. Great variation in the length of the major septa is observable, and these septa are strongly convex towards the fossular break. The tabulæ are strongly depressed in the middle. The above description refers to adult specimens, which are usually about 4 cm. long. Although the septa are thickened, this feature does not appear to be quite so pronounced as in the Gower specimens.

[1] E. E. L. Dixon, 'The Carboniferous Succession in Gower' Q. J. G. S. vol. lxvii (1911) p. 553.

CANINIA cf. PATULA Michelin. (Fig. 4 & Pl. X, fig. 6.)

Dr. Vaughan distinguished two forms of this species in the *Caninia* zone of the Carboniferous succession in the Mendip region.[1] The two forms described are respectively widely septate and closely septate, the former being the more common. In both cases minor septa are undeveloped, but the major septa extend through the zone of vesicles to the wall. The specimens obtained from Ticknall closely resemble *C. patula* Michelin in most points, but there is a distinct development of short minor septa. Dr. Vaughan considered the Ticknall mutation as being a late derivative of a

Fig. 4.—Caninia *cf.* patula *Michelin. Natural size.*

[Specimen from which the transverse section shown in Pl. X, fig. 6, has been cut.]

widely-septate patulid *Caninia*. The main features of this late mutation are:—

> The coral rapidly widens, frequently attaining a length of 5 cm., and the calyx is very deep. A horizontal section cut through an adult specimen just below the calyx shows:—
>
> 1. The major septa continuous through the wide vesicular zone.
> 2. The thickening of the major septa.

[1] S. H. Reynolds & A. Vaughan, 'Faunal & Lithological Sequence in the Carboniferous Limestone Series (Avonian) of Burrington Combe (Somerset)' Q. J. G. S. vol. lxvii (1911) p. 375.

3. A well-marked cardinal septum.
4. The development of short minor septa through the zone of vesicles.
5. The tendency to form an inner wall consisting of arcs proceeding from septum to septum.

A comparison of fig. 2 of the Burrington Combe paper with the cross-section (Pl. X, fig. 6 of this paper), will indicate the similarity between the fossulæ and tabulæ of the two types,—that obtained from the *Caninia* horizon of the Mendip area and that from the D_2–D_3 beds of Ticknall.

DIPHYPHYLLUM, near CONCINNUM Lonsdale, large form.

A very large form of *Diphyphyllum*, measuring 18 mm. across the calyx, occurs somewhat sparingly at Breedon Cloud. It is usually obtained in an incomplete form, the central area being absent; but Mr. R. Wood has collected one or two specimens in which the tabulæ and discontinuous columella are preserved. It is compound cylindrical usually, though sometimes a polygonal habit is developed. On account of this latter characteristic and the absence of the central area, this species has previously been assigned to *Lonsdalia floriformis*; but, owing to the kindness of Dr. Stanley Smith who examined the material, I am able to state that no specimen of *Lonsdalia* occurs at Breedon Cloud.

The nearest *Lithostrotion* equivalent to this large form of *Diphyphyllum* appears to be *L. affine*. Specimens of *Diphyphyllum concinnum* with polygonal habit also occur in the highest beds on the western side of Breedon-on-the-Hill.

SYRINGOPORA GIGANTEA Thomson.

A large *Syringopora*, the corallites of which are about 4 mm. in diameter, has been found at Breedon Cloud. In its general characters this species approximates to the large form described by James Thomson in the Proceedings of the Glasgow Philosophical Society.[1] The species is of very rare occurrence in England, and it is interesting to note that specimens have been found in Dovedale in the south-western part of the Midland area.

IX. NOTE ON THE TONGE BORING.

A boring made at Tonge in Leicestershire yielded results which appear to indicate that—

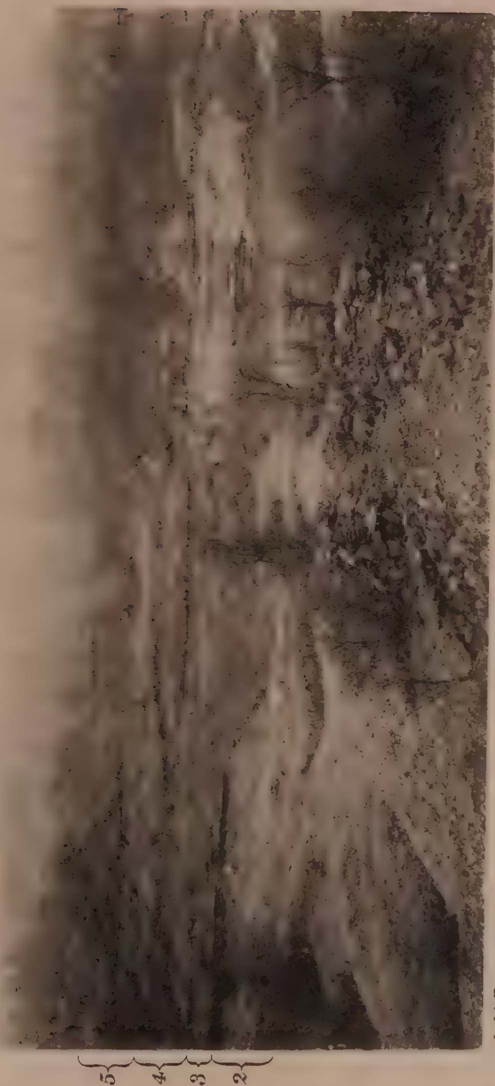
(1) The throw of the Breedon Fault may be at least 300 feet;
(2) The Keuper at that locality is about 279 feet thick;
(3) The Millstone Grit was either poorly developed or much eroded before the deposition of the Trias;
(4) The 'Pendleside' Shales died out somewhere between Tonge and Breedon, so that the Millstone Grit is locally unconformable upon the Carboniferous Limestone.

[1] Vol. xiv (1883) p. 329.

L.M.P., photo.

Bemrose, Collo, Derby

TICKNALL: THE CAVERNS.



L.M.P., photo.

Bemrose, Collo, Derby.

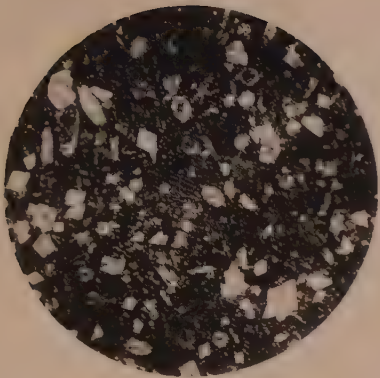
TICKNALL: THE MAIN EXPOSURE.

L.M.P., photo.

Bemrose, Collo, Derby.

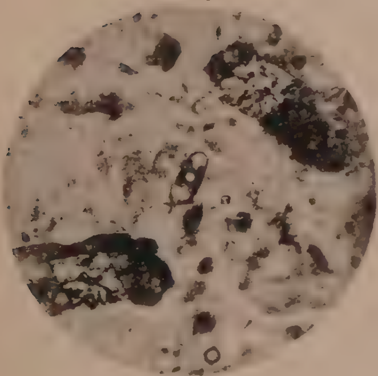
BREEDON CLOUD: THE FAULT NEAR THE SOUTHERN END.

1.

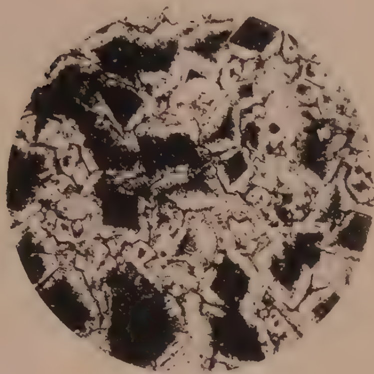


2.

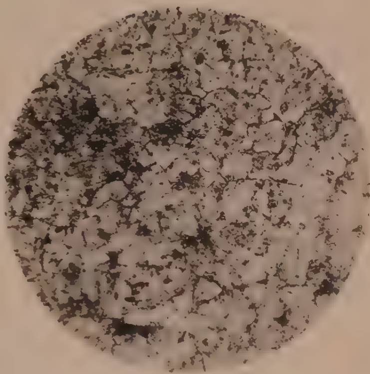
3.



4.



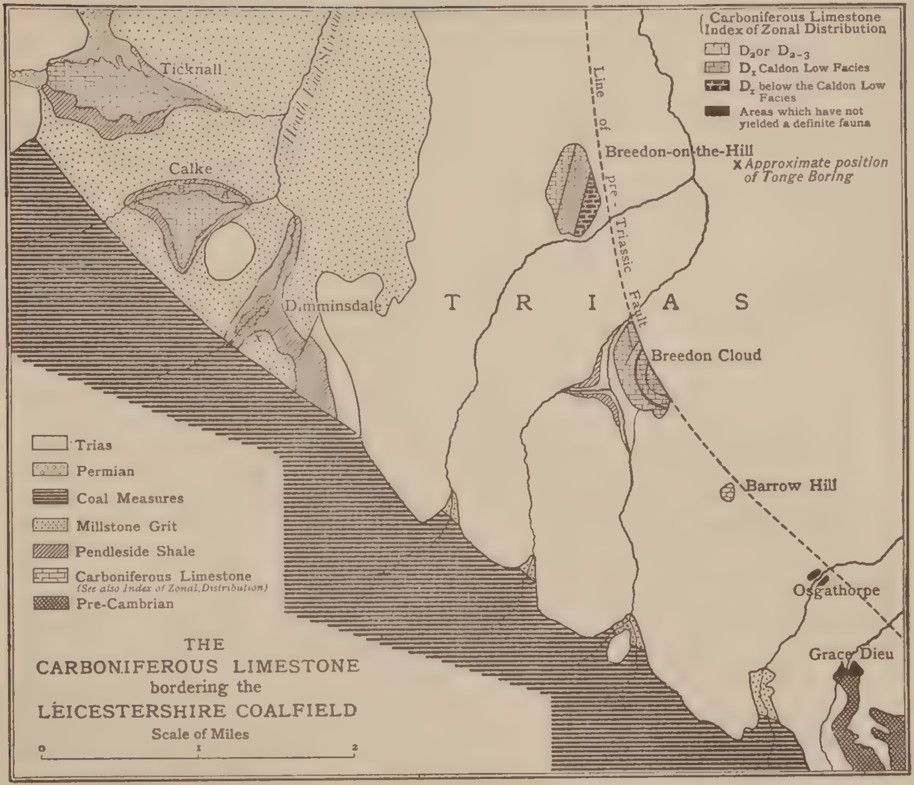
5.



6.

G. S. S., photomicro.

Bemrose, Collo., Derby.



[Owing to an oversight, the belt of 'Millstone Grit' south-south-east of Dimminsdale has been left blank. It should have been dotted like the other 'Millstone Grit' outcrops.]

The various strata passed through in the boring may be summarized briefly as follows:—

		Thickness in feet.
Red marls with veins of gypsum	=Keuper	about 279
Grey sandstones	=Millstone Grit	about 9
Thin grey limestones, with dark shales and thicker limestones below.	=Carboniferous Limestone	about 82
	Total depth of boring...	370

EXPLANATION OF PLATES VII–XI.

Plate VII.

Exposures at Ticknall: the Caverns: 5=dolomites; 4=thinly-bedded limestones with *Productus*; 3=sandy stratum; 2=foraminiferal dolomitic limestones; 1=Encrinital limestones and shales.

Plate VIII.

The main exposure at Ticknall; 5=yellow and grey dolomites; 4, 3, 2 as in Pl. VII.

Plate IX.

The southern fault at Breedon Cloud, showing thinly-bedded red dolomite above thicker yellow dolomites with chert.

Plate X.

Fig. 1. Ticknall dolomitic limestone: calcite stained with Lemberg's solution. × 25 diameters. (See p. 90.)

2. Ticknall grey dolomite. Compare the degree of idiomorphism with that of fig. 5. × 25 diameters. (See p. 90.)

3. Organic limestone, Calke Park. Idiomorphic rhombohedra of dolomite containing limonite, not arranged in any particular order. Note the invasion of organic structures by the rhombohedra of dolomite. × 20 diameters. (See p. 93.)

4. Dolomite from the upper beds at Breedon-on-the-Hill. Hæmatite inclusions arranged zonally, clear outer margins. Dolomite of Triassic origin. × 25 diameters. (See p. 105.)

5. Dense yellow dolomite, Breedon Cloud. Finer grain than in the Ticknall dolomite. × 25 diameters. (See p. 105.)

6. Transverse section of *Caninia* cf. *patula* Michelin. Natural size. (See p. 107.)

Plate XI.

Geological map of the Carboniferous Limestone bordering the Leicestershire Coalfield, on the scale of 1 inch to the mile, or 1 : 63,360.

Discussion.

Mr. E. E. L. Dixon, after congratulating the Author and remarking on the close connexion of the Leicestershire Carboniferous Limestone with the Derbyshire and Wrekin developments as against those found in South Wales and Clee Hill, asked the Author on what evidence the shales between the highest limestone and the Millstone Grit were assigned to the Pendleside Series.

The latter are characterized by a definite fauna, and probably occupy a definite position in the Carboniferous System. In view of the fact that, outside the Leicestershire area, the top of the limestone is of markedly different horizon in different places, even where it is succeeded conformably by argillaceous strata or by beds of Millstone-Grit facies, it is necessary that the term 'Pendleside Series' should be confined to beds containing its characteristic fauna, otherwise it will become as meaningless as the term 'Millstone Grit.'

As to the origin of certain dolomites described in the paper, he had found that the corals enclosed in Carboniferous limestones afforded valuable criteria for judging whether dolomitization was 'contemporaneous' or of later origin (the latter including that due to Triassic infiltration). In 'contemporaneous' dolomites the coral-tissue resists dolomitization as compared with the matrix, whereas in Carboniferous limestones dolomitized later the corals are altered before the matrix. As the corals exhibited from Breedon were dolomitized, in preference to their matrix, their alteration must be of later age. Possibly the bulk of the rock was altered 'contemporaneously,' and the process extended, by percolating waters, to the undolomitized organic remains at a later date.

The CHAIRMAN (Dr. A. SMITH WOODWARD) referred to the remarkable state of preservation of the teeth of Elasmobranch fishes obtained from the shales at Ticknall by the late Edward Wilson, F.G.S. They added much to our knowledge of these rare fossils.

Sir HENRY HOWORTH and Prof. W. W. WATTS also spoke.

The AUTHOR thanked the Fellows present for their kind reception of his paper, and expressed his gratitude to Sir Henry Howorth and Prof. Watts for their kind remarks. In reply to Mr. Dixon, he drew attention to evidences of contemporaneous dolomitization afforded by the bedded nature of the dolomites, the non-existence of any lateral transition into normal limestones, and the absence of any apparent connexion between faulting and dolomitization. Fossils obtained from the greater part of the sequence were completely converted into dolomite.

Although the shales lying between the Carboniferous Limestone and the Millstone Grit had not yielded a typical Pendleside fauna, these beds had been designated 'Pendleside' in the paper, in order to compare their development with that of the strata which occupy a corresponding position in the Carboniferous sequence of Derbyshire.

6. *The* Carboniferous Limestone Series *on the* South-Eastern Margin *of the* South Wales Coalfield.

By Frank Dixey, M.Sc., F.G.S., and Prof. Thomas Franklin Sibly, D.Sc., F.G.S., University College of South Wales & Monmouthshire, Cardiff. (Read March 28th, 1917.)

[Plates XII–XVI.]

Contents.

I. Introduction.

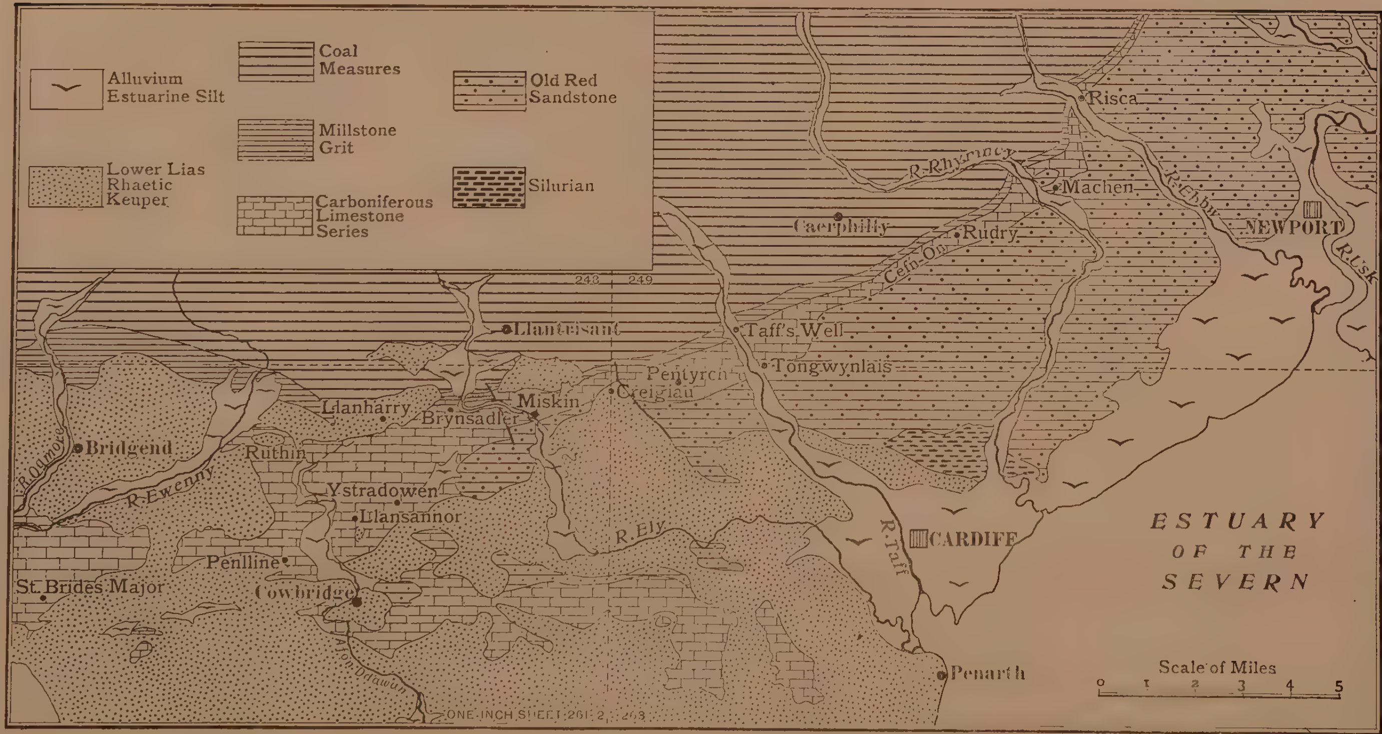
The outcrop of Carboniferous Limestone which is the subject of this communication extends from the valley of the Ewenny River about 3 miles east of Bridgend (Glamorgan) to the valley of the Ebbw River at Risca (Monmouth), a distance of about 19 miles from west-south-west to east-north-east.[1] It lies on the south-eastern margin of the South Wales coal-basin, and belongs in its western portion to the northern limb of the Cardiff–Cowbridge anticline (see map, fig. 1, p. 112).

The area within which this outcrop is comprised was mapped by the officers of H.M. Geological Survey (Dr. A. Strahan, Mr. R. H. Tiddeman, and Mr. T. C. Cantrill), in the course of the re-survey of the South Wales Coalfield, and the results were embodied in the official maps and memoirs.[2] The present paper supplements the description of the Carboniferous Limestone Series given in those publications, in the light of recent researches on the Carboniferous rocks of this country and Belgium by the late Dr. A. Vaughan and others.

[1] As regards the field-work upon which this paper is based, all that portion of the outcrop which lies west of the river Taff has been investigated by Mr. Dixey, and the portion east of the Taff by Prof. Sibly. In the absence of Mr. Dixey on military service, the whole paper has been written by Prof. Sibly.

[2] Newport sheet (N.S. 1-inch map 249) and 'The Country around Newport' 1899, 2nd ed. 1909; Cardiff sheet (N.S. 1-inch map 263) and 'The Country around Cardiff' 1902, 2nd ed. 1912; Bridgend sheet (N.S. 1-inch map 261 & 262) and 'The Country around Bridgend' 1904. These Memoirs will be referred to as the 'Newport Memoir,' the 'Cardiff Memoir,' and the 'Bridgend Memoir,' respectively.

Fig. 1.—*Geological map of the neighbourhood of Cardiff, based on the maps of the Geological Survey.*



The nature and significance of the broad variations shown by the Carboniferous Limestone Series in the extensive South Wales outcrops have been admirably defined by Dr. Strahan in the following words:—

'The Carboniferous Limestone Series presented a succession of stages in development. The fullest development was exhibited in the southernmost occurrences, as regarded both the sequence and the thickness of zones. A second stage, showing an incomplete sequence and considerable attenuation, with indications of near-shore origin, was presented along parts of the margin of the coalfield. Lastly, in the northernmost occurrences, near Abergavenny and at Pen-cerig-calch, the series dwindled away to 100 feet or less, while in Pembrokeshire it was wholly overstepped. The inference followed that the coast-line ran through Pembrokeshire, and not far north of Abergavenny.'[1]

Within the comparatively small extent of outcrop now under consideration the Carboniferous Limestone Series undergoes a remarkable change. Here, as in most parts of South Wales, two lithological divisions are recognized: namely, the Lower Limestone Shales and the Main Limestone. Not only does the whole series suffer a notable diminution of thickness when traced north-eastwards along the outcrop, but simultaneously the Main Limestone changes in character from a formation composed chiefly of ordinary crinoidal limestones and oolites into an almost uninterrupted succession of dolomites.[2] The elucidation of this change has been the object of our investigations.

Little zonal work had preceded our studies in the district. In the east of the area Mr. E. E. L. Dixon,[3] who examined the outcrop for the purpose of collecting information for the second edition of the Newport Memoir, recognized the equivalence of the Lower Limestone Shales to the *Cleistopora* Zone, and noted the presence of the *Seminula* Zone in the Taff valley. That geologist further attributed the absence of the *Dibunophyllum* Zone in the Taff valley, and the apparent attenuation of the *Seminula* Zone farther east, to unconformable overstep by the Millstone Grit, a conclusion which is confirmed by additional evidence adduced in this paper.

In the west of the district, a visit to the neighbourhood of Miskin and Llanharry in 1909 enabled Prof. G. Delépine to recognize the *Zaphrentis*, *Caninia*, *Seminula*, and *Dibunophyllum* Zones in the Main Limestone of that area.[4] Our own observations accord with those of Prof. Delépine, except as regards his identification of the *Dibunophyllum* Zone: the exposures near Llanharry which he assigns to the subzones D_1 and D_2 are referred by us to the *Seminula* Zone. The subzone D_1 is represented in ground

[1] Q. J. G. S. vol. lxvii (1911) p. 567 (in discussion of the paper by E. E. L. Dixon & A. Vaughan on 'The Carboniferous Succession in Gower').

[2] Newport Memoir, 2nd ed. p. 19; and Bridgend Memoir, p. 6.

[3] Newport Memoir, 2nd ed. p. 20.

[4] 'Note on the Faunal Succession in the Carboniferous Limestone (Avonian) near Llantrisant Station in the Bridgend area, South Wales' Geol. Mag. dec. 5, vol. viii (1910) pp. 67–70.

immediately north of that examined by Prof. Delépine near Llanharry, and also in the outcrop farther west; but D_2 has not been recognized anywhere within the district here described.

In our description and interpretation of the lithological succession, we are guided very largely by Mr. Dixon's luminous researches on the Carboniferous Limestone of Gower. The joint paper by him and the late Dr. A. Vaughan, dealing with that area, will be referred to as the 'Gower paper.'[1] Several lithological terms applied by Mr. Dixon to special rock-types, and defined in the Gower paper, will be employed.

It would be difficult to exaggerate our indebtedness to the publications of the Geological Survey: to the maps,[2] for providing an invaluable basis for our zonal mapping, and to the memoirs for much information and guidance. We wish to express our thanks to Dr. A. Strahan, Director of H.M. Geological Survey, for permission to examine specimens in the Survey collection, and for facilitating access to the original field-maps of the district.

II. Structure and Physical Features of the Outcrop.

On the east, the deep gorge through which the Ebbw River escapes from the coalfield at Risca marks one extremity of the area dealt with in this paper. At that point the outcrop of the Carboniferous Limestone, followed from the west, has just swung into a direction a little east of north, to persist in a much attenuated form along the eastern margin of the coalfield. In the west, near Ruthin, St. Mary Hill, and Penlline,[3] the Carboniferous Limestone disappears beneath a cover of Keuper and Lias, to reappear south and west of Bridgend, and outside the area now under consideration, in extensive outcrops around St. Bride's Major and Porthcawl.

The Main Limestone forms an escarpment ridge which, although much more pronounced in the eastern than in the western part of the outcrop, remains well-developed as far west as Llansannor. Three rivers flowing from the coalfield breach this ridge. Named in order from east to west, these are: the Rhymney, which breaks through in a deep, narrow valley at Machen, only 2 miles distant from the Ebbw River at Risca; the Taff, which flows in a notably steep-sided, narrow gorge (Pl. XIII, fig. 1) between Taff's Well and Tongwynlais; and the Ely, which crosses the limestone in a much wider, shallower valley at Miskin. Farther west, the river Dawen rises on the limestone near Llanharry, and flows southwards between Llansannor and Penlline to Cowbridge. These rivers traverse the country with a complete disregard of geological

[1] 'The Carboniferous Succession in Gower (Glamorganshire)' Q. J. G. S. vol. lxvii (1911) p. 477.

[2] Particularly the 6-inch maps with geological lines, published in the case of all sheets which include outcrops of Coal Measures.

[3] The spelling adopted is that of the latest edition of the 1-inch Ordnance Survey map.

structure,[1] save for the probably significant fact that both the Taff and the Ely cross the Carboniferous Limestone on lines of dip-faulting.

The limestone ridge attains an altitude of more than 900 feet between the Ebbw and the Rhymney, although it is there no more than a feature on the south-eastern slope of Mynydd Machen (Pl. XII, fig. 3). Strongly developed all the way from the Rhymney to the Taff, it rises above 800 feet in Cefn-On (Pl. XII, figs. 1 & 2) and Cefn Carnau. West of the Taff, it remains sharply defined, with a steep scarp-face, through Garth Wood (Pl. XIII, fig. 2) as far as Pentyrch; but it dies down at Creigiau, and in the outcrop west of that place never approaches its eastern development.

The striking development of the Main Limestone escarpment in the eastern part of the district here described results from a remarkable adjustment of minor drainage-lines to geological structure in that part of the coalfield margin. Tributaries of the Rhymney and the Taff, selecting the outcrops of the less resistant bands, such as the Lower Limestone Shales, together with the topmost beds of the Old Red Sandstone, and the shales which form the lower part of the Millstone Grit, have entrenched themselves in strike-valleys along those lines (see map, Pl. XVI, and photographs, Pl. XII, figs. 1 & 2). Between the Ebbw valley and the Taff valley, the quartz-conglomerates which lie at the base of the Upper Series of the Old Red Sandstone have determined a bold escarpment which runs parallel to the limestone ridge. This is magnificently developed in Craig Lysfaen, Craig Llanishen, and Coed-y-Wenallt, between the Rhymney and the Taff. The most notable of the strike-valleys mentioned above is Cwm Draethen (Pl. XII, fig. 2), which separates Craig Lysfaen and Craig Ruperra from the limestone ridge on the north. In this valley the Draethen brook (Nant-y-Draethen), rising on the dip-slope of Craig Lysfaen, follows the boundary of the Old Red Sandstone and the Lower Limestone Shales for about 3 miles, in its rapid descent to the Rhymney at Draethen. In the upper part of Cwm Draethen, as in several other portions of the outcrop, the valley is relieved by a low ridge formed by a group of limestones in the Lower Limestone Shales. This feature, illustrated in Pl. XII, figs. 1 & 2, is further described on pp. 125–26.

Within the Main Limestone itself, variations of lithology are often clearly expressed in the surface relief. This is particularly the case in the outcrop east of the Taff valley, where less resistant bands in the Main Limestone are frequently marked by depressions. For example, a well-defined dry valley east of Rudry marks a group of dolomite-mudstones and shales in the middle of the Main Limestone; and on the eastern side of the Rhymney valley the lithological difference between the lower half of the Main

[1] A. Strahan, 'On the Origin of the River-System of South Wales, & its Connexion with that of the Severn & the Thames' Q. J. G. S. vol. lviii (1902) p. 207.

Limestone, consisting of hard crystalline dolomites, and the upper half, composed mainly of dolomite-mudstone, is clearly reflected in the form of the ground (Pl. XII, fig. 3).

The prevalent northerly to north-westerly dip of the strata is seldom interrupted. At Machen, however, a sharp roll brings up an inlier of Old Red Sandstone, and at Tongwynlais anticlinal and synclinal rolling of the Lower Limestone Shales results from a similar disturbance. North of Ystradowen, another anticline involves the Lower Limestone Shales and the lower beds of the Main Limestone: this is one of several minor folds developed in the westward-pitching 'nose' of the Cardiff–Cowbridge anticline. On Mr. T. C. Cantrill's interpretation of the structure,[1] the main axis of the Cardiff–Cowbridge anticline coincides with the faulted anticline of Penlline, and thence passes eastwards a little to the south of Llansannor, thus traversing the south-western corner of the area described in this paper.

Faulting of the Carboniferous Limestone is practically confined to dip-faults, which belong to the well-marked north-north-westerly fault-system[2] of the coalfield. These vary from small local fractures to displacements of considerable magnitude, the largest being the Taff's-Well Fault, the Creigiau Fault, and the Miskin Fault. Both the Taff's-Well Fault, which is regarded by Dr. Strahan as a continuation of the Darenddu Fault of the coalfield,[3] and the Creigiau Fault, which involves the Keuper, Rhætic, and Lias,[4] are attended by much shattering of the Carboniferous Limestone.

In the area east of the Taff valley, no vestige of Mesozoic deposits remains on the Carboniferous Limestone, and the outcrop of the latter is almost wholly free from Glacial drift. West of the Taff the case is very different: a cover of Trias and Lias conceals a large part of the Carboniferous Limestone Series immediately west of the Creigiau Fault, and the Keuper oversteps the northern limit of the Main Limestone almost continuously in the ground west of Brofiscin. Glacial drift is widespread: it conceals the Lower Limestone Shales effectually over large tracts, and covers a great part of the Main Limestone west of the Ely valley.

III. Note on the Dolomitization.

Dolomites bulk very largely in the Carboniferous Limestone of this district, and in the area east of the Taff valley they compose the Main Limestone almost to the exclusion of non-dolomitic limestones. Both contemporaneous dolomites and vein-dolomites (subsequent dolomites) are developed extensively, but the former in much larger amount than the latter.[5]

[1] Bridgend Memoir, pp. 7–8, with sketch-map (fig. 1, p. 8).
[2] Newport Memoir, 2nd ed. p. 4. [3] *Ibid.* pp. 25, 71.
[4] Cardiff Memoir, 2nd ed. pp. 47, 72.
[5] Methods of distinguishing contemporaneous and subsequent dolomitization are discussed by Mr. E. E. L. Dixon, in 'The Country around Swansea' Mem. Geol. Surv. 1907, pp. 13–20 & pls. i–ii.

Mr. E. E. L. Dixon pointed out the contemporaneous origin of most of the dolomitization in the outcrop comprised in the Newport map, which includes the eastern part of our area, and we cannot do better than quote his words :—

'From the fact that the dolomite is comparable with that of Gower, and persists as such for upwards of 15 miles, it may be inferred that much of the dolomitization was "contemporaneous" rather than the result of subsequent alteration along veins or faults. That the rocks were at first calcitic is shown by their containing crinoidal remains, and the expression "contemporaneous" is intended as implying dolomitization while they were still under the influence of the Carboniferous Limestone sea. One of the bands, however, in the argillaceous group was examined under the microscope, and found to have been a dolomite-mud, such as might have been derived from the detrition of dolomites.'[1]

Vein-dolomitization, due to a much later metasomatism, is widespread, being particularly well developed, for example, in the *Seminula* Oolite of Creigiau and the Taff valley. Its great development in the localities mentioned may be attributed to free circulation of magnesian waters in highly-fissured limestones adjacent to large faults, but elsewhere it appears to have resulted chiefly from diffuse permeation.

Inasmuch as contemporaneous dolomitization was induced by conditions which accompanied the deposition of the Carboniferous Limestone, whereas the distribution of vein-dolomitization bears no relation to those conditions, we have attempted a systematic discrimination; and the nature of the dolomitization as inferred by us is expressed by means of conventional signs in the sections illustrating this paper. Discrimination is often uncertain, however, and no uniform accuracy is claimed. Moreover, it is probable that many cases occur in which limestones partly altered by contemporaneous dolomitization were further affected by vein-dolomitization at a later date.

IV. General Account of the Succession and its Lateral Variation.

The Lower Limestone Shales rest conformably upon the Upper Old Red Sandstone. The Main Limestone is succeeded unconformably by the Millstone Grit, the base of the latter formation overstepping from higher to lower horizons in the Main Limestone when traced north-eastwards along the outcrop. In general, shales form the lower member of the Millstone Grit; but locally, in the east of the district, a quartz-conglomerate is developed at the base of that formation.

The vertical sections (fig. 2, p. 119) illustrate the general lithology,

[1] Newport Memoir, 2nd ed. pp. 19–20. Specimen E 7423 in the collection of the Geological Survey represents the band mentioned in the last sentence quoted. It is to rocks of this type, largely developed in the sequence east of the Taff, that the term d o l o m i t e - m u d s t o n e is applied in this paper.

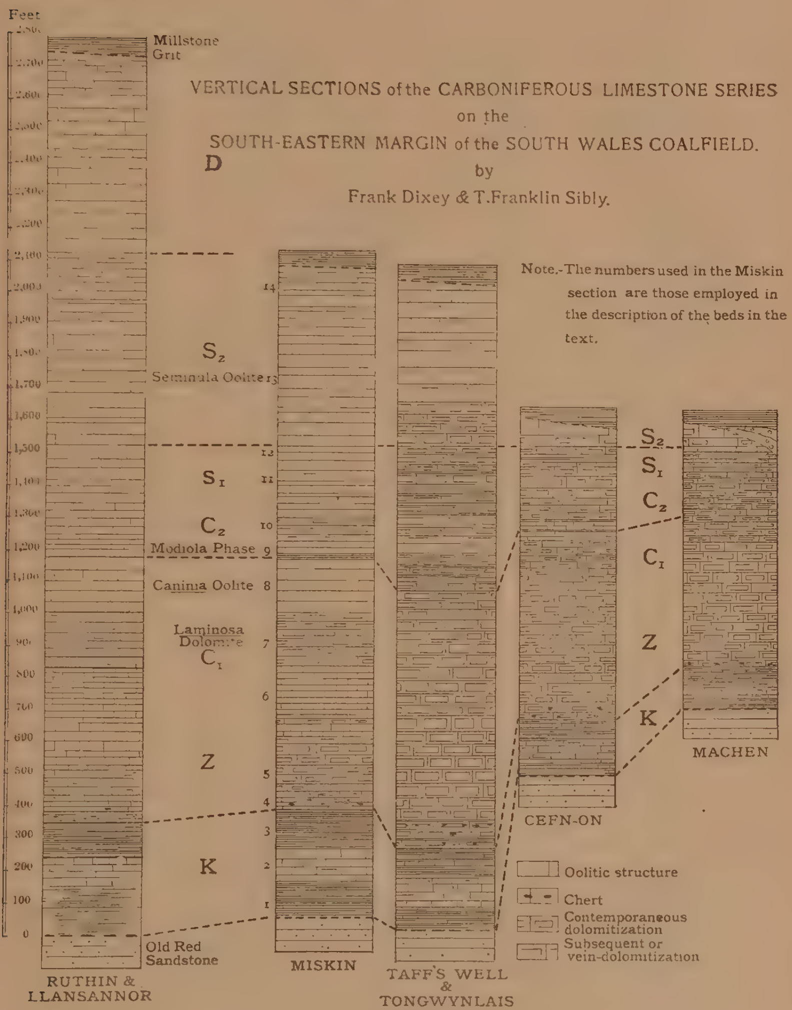
SYNOPSIS OF THE SUCCESSION IN THE WESTERN PART OF THE OUTCROP (WEST OF THE CREIGIAU FAULT).

	Zone or Subzone.		*Approximate thickness in feet.*	
Upper Avonian.	*Dibunophyllum* Zone [1] (?) D_2 (in part). D_1	Limestones, including pseudobreccias.	600 (seen)	Main Limestone.
	Main *Seminula* Zone S_2.	*Modiola* phase, characterized especially by limestones with pisolitic structures. *Seminula* Oolite.	550 to 600	
	Upper *Caninia* Zone C_2+S_1.	Limestones, including much oolite. *Modiola* phase.[2]	350	
Lower Avonian.	Lower *Caninia* Zone C_1.	*Caninia* Oolite. *Laminosa* Dolomite. (γC_1) Crinoidal limestones.	550	
	Zaphrentis Zone Z.	Crinoidal limestones and dolomites: chert near the base.	250	
	Cleistopora Zone K.	(K_2) Shales with thin limestones. (K_1 or K_2) Crinoidal limestone and oolite. (K_1)[3] Limestones and shales.	300 to 350	Lower Limestone Shales.

1 Present only in the area west of the Ely River.
2 Detected at one locality only (Miskin).
3 Correlation inferred from the development east of the Taff, where the Lower Limestone Shales are better exposed and K_1 is found to contain a *Modiola* phase characterized by limestones of *a*-type.

as well as the zonal correlation, of the succession at several points along the outcrop. The accompanying table (p. 118), which

Fig. 2.



summarizes the sequence in the western part of the area, where the development of the Avonian is most nearly complete, embodies the essential features of the Ruthin and Miskin sections of fig. 2.

Fig. 3.—*Horizontal section through the Carboniferous Limestone Series of Miskin.* (F. Dixey.)

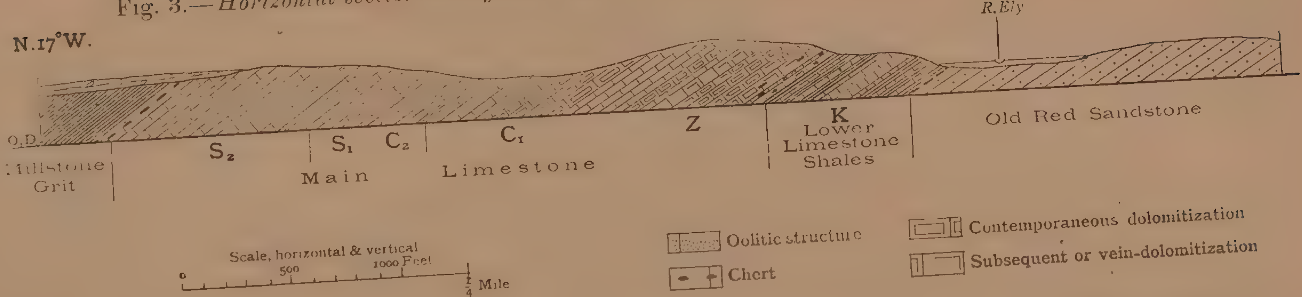
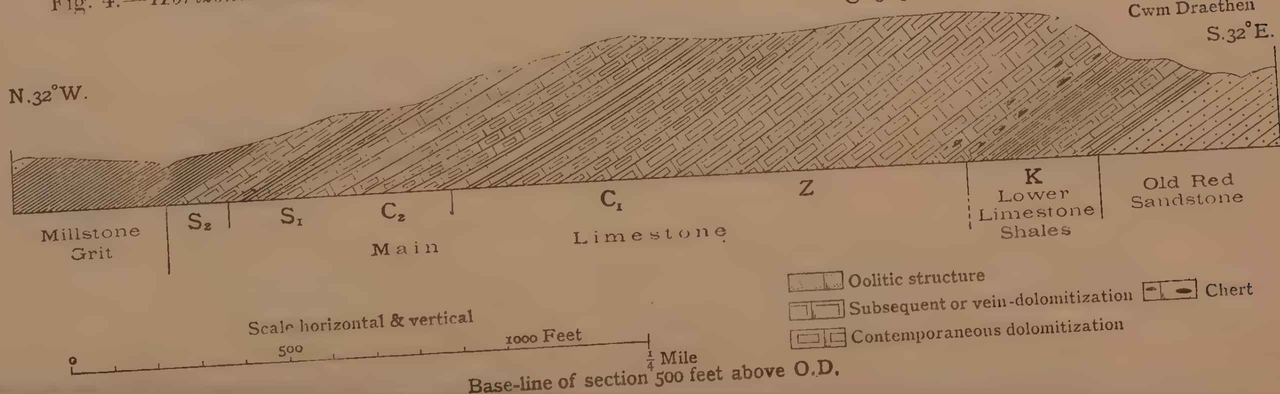


Fig. 4.—*Horizontal section through the Carboniferous Limestone Series of Cefn-On.* (T. Franklin Sibly.)



At the western end of the district here dealt with, around Ruthin, Penlline, and Llansannor, the total thickness of the Carboniferous Limestone Series probably approximates to 2750 feet, made up as follows:—

	Feet.	
D (D_1 and (?) D_2 in part)	600	Main Limestone.
S_2	600	
C_2+S_1, C_1 ..., Z	1200	
K .	(?)350	Lower Limestone Shales.
Total	2750	

The thickness here assigned to K is conjectural. The other figures may be regarded as fair approximations. A cover of Trias conceals the junction of the Main Limestone with the Millstone Grit. D_3 has not been recognized, and, if represented, it is most probably incomplete. The Lower Limestone Shales, in so far as they are exposed, present a normal facies of limestones and shales. The Main Limestone is composed essentially of undolomitized crinoidal limestones and oolites, with a standard fauna. The upper part of S_2, however, shows the lagoon-phase deposits which are so characteristic of that horizon[1] over most of the South-Western Province: and contemporaneous dolomitization of the limestone is important at two levels: (1) in Z, and (2) in C_1—the *Laminosa* Dolomite. A *Modiola* phase at the base of C_2, detected at Miskin, about 4 miles away to the east, may be present, but has not been proved.

At the north-eastern extremity of the area here described, that is, in the Ebbw valley at Risca, the total thickness is reduced to about 800 feet, made up as follows:—

	Feet.	
C_2+S_1, C_1 ..., Z	675	Main Limestone.
K	125	Lower Limestone Shales.
Total	800	

There the Main Limestone is almost wholly dolomitic. Its lower portion, about 400 feet thick, consists entirely of crystalline dolomites representing contemporaneously-altered standard limestones, in which occasional crinoid-ossicles are practically the only surviving fossils. Its upper portion, about 275 feet thick, is composed almost wholly of dolomite-mudstones with intercalated bands of crystalline dolomite, but includes a very small thickness of calcitic oolite and calcite-mudstone near the summit. In this upper portion, the dolomitic beds are barren, but the calcitic beds contain ostracods and foraminifera: this is essentially a thick *Modiola* phase, characterized by a great development of dolomite-

[1] E. E. L. Dixon, Gower paper, p. 514.

mudstone, which ranges from some level in C_1 up into S_1. The Lower Limestone Shales of the Ebbw valley, on the other hand, are unaffected by contemporaneous dolomitization, and present a normal, fossiliferous character.

Between the Ewenny valley and the Ebbw valley, therefore, the *Dibunophyllum* Beds and the Main *Seminula* Zone are cut out by overstep of the Millstone Grit; while the surviving members of the Main Limestone suffer much attenuation, and change from a mainly non-dolomitic series of standard limestones into an almost unbroken succession of crystalline dolomites and dolomite-mudstones. The Lower Limestone Shales, though also suffering attenuation, maintain their character substantially unaltered.

In the western part of the district, a well-defined series of zonal divisions in the Main Limestone can be traced as far east as the neighbourhood of the Creigiau Fault. But contemporaneous dolomitization increases rapidly in its vertical extent as we proceed eastwards, and obliterates part of this zonal succession in the outcrop between the Creigiau Fault and the river Taff. In the Taff valley, contemporaneous dolomitization has affected almost the whole of the Main Limestone up to, and including, the basal beds of S_2; but the bulk of S_2 has escaped alteration, except for localized vein-dolomitization. East of the Taff valley the greater part of S_2 is soon cut out by overstep. The surviving members of the Main Limestone remain almost wholly dolomitic; but in C_2, and again at the base of S_2, the formation of dolomite has been partly due to vein-dolomitization. Dolomitization and the development of *Modiola*-phase deposits obliterate the faunal succession so largely that only two zonal horizons can be traced in the Main Limestone east of the Taff: these are (1) Z_1, which can be recognized at a few localities, and (2) the base of S_2, a well-marked horizon which can be traced as far as the Rhymney valley, where it is overstepped by the Millstone Grit. The *Modiola*-phase deposits, essentially dolomite-mudstones with subordinate calcite-mudstones, become conspicuous in the upper part of the Main Limestone a little east of the Taff, and increase in a north-easterly direction until, in the ground between the Rhymney and the Ebbw, they form nearly half of the Main Limestone as there developed.[1]

Attenuation of the strata.—Marked attenuation in a north-easterly direction from the Taff valley is shown by the Lower Limestone Shales and those divisions of the Main Limestone which persist. As regards the Lower Limestone Shales, estimates of thickness west of the Taff are of little value, owing to the prevalence of drift; but a great reduction of thickness north-eastwards from the Taff valley, from about 260 feet at Tongwynlais to

[1] These constitute an argillaceous group which, as stated in the Newport Memoir (2nd ed. p. 20) 'appears at Risca and runs thence south-westwards . . . .' It is in consequence of unconformable retrogression of the Millstone Grit, as the Carboniferous Limestone is traced from the north-east, that the beds in question make their appearance in the Ebbw valley at Risca.

125 feet at Risca, is indisputable. In the Main Limestone, account can only be taken of the sequence, Z to S_1, as a whole, because an accurate delimitation of C_1 and C_2 is only possible in the neighbourhood of Miskin: elsewhere west of the Taff, and in the almost barren dolomitic series east of the Taff, the C_1 C_2 boundary can only be sketched. The thickness of the series, Z to S_1, estimated at 1130 feet near Miskin, probably increases south-west of that place. Eastwards from Miskin it increases to at least 1250 feet in the Taff valley, owing to expansion of the C_2+S_1 beds. East of the Taff, however, where the outcrop of the strata is trending north-eastwards, it diminishes to 850 feet on Cefn-On, and to between 650 and 700 feet near Machen.

Overstep of the Millstone Grit.—Overstep is very gradual along most of the outcrop, but it becomes rapid at those points where the zones of the Carboniferous Limestone swing north-eastwards,[1] namely: (1) in the ground west of the Ely, (2) immediately east of the Taff, and (3) immediately east of the Rhymney.

In the area west of the Creigiau Fault, the junction of Carboniferous Limestone and Millstone Grit is everywhere concealed, either by Keuper or by Glacial deposits. But the rate of overstep is undoubtedly rapid in the ground west of the Ely, and slow east of that river. At Ruthin, the *Dibunophyllum*-Beds have a thickness of at least 600 feet; but near Brynsaddler, 4 miles away to the east, the position of the Millstone-Grit boundary, deduced from Mr. S. Vivian's section of the Trecastle iron-mine,[2] indicates that only about 100 feet of the *Dibunophyllum* Zone survives. On the other hand, overstep does not progress much below the base of D in the distance of 6 miles between Brynsaddler and the Taff valley.

East of the Taff valley the base of the Millstone Grit can, as a rule, be traced with considerable accuracy. No actual junction with the Carboniferous Limestone is, however, exposed.[3] Rapid overstep cuts out at least 300 feet of the S_2 beds in a distance of little more than a mile north-east of the Taff valley, and another sharp transgression takes place immediately east of the Rhymney. This latter transgression, which carries the Millstone Grit across the base of S_2 and far down into the underlying beds, probably into C_1, coincides with the development of a thick lenticle of quartz-conglomerate at the base of the Millstone Grit. It leads to the maximum overstep of the Millstone Grit within the district here dealt with, at a point midway between the Rhymney

[1] The significant trend is, of course, that of the base and zones of the Carboniferous Limestone. Inasmuch as overstep is causing rapid attenuation of the outcrop of the Carboniferous Limestone at these very points, the trend of that outcrop as a whole has no significance in this connexion.

[2] Trans. S. Wales Inst. Eng. vol. xiv, No. 3 (1885) pl. xxvi. Reproduced in the Bridgend Memoir, fig. 11, p. 109.

[3] The junction formerly exposed in a railway-cutting on the western side of the Ebbw valley (Newport Memoir, 2nd ed. p. 21) is now concealed.

and the Ebbw rivers. Northwards from that point, towards Risca, the quartz-conglomerate dies out, and simultaneously the base of the Millstone Grit retrogresses, uncovering the C_2+S_1 beds on the western side of the Ebbw valley, but not recrossing the base of S_2. The retrogression is, however, merely a local incident. Immediately north of the Ebbw river, just outside the limit of the area here described, the Millstone Grit resumes its overstep on to lower beds in the Main Limestone.

V. Detailed Description of the Succession.

Note in regard to localities.—Important localities throughout the district have been indicated upon our copies of the 6-inch Ordnance Survey maps by symbols or locality-numbers, as, for example, λ 1, λ 2. The complete descriptive symbol for any locality therefore consists of the number of the appropriate 6-inch sheet (Glamorgan or Monmouth), followed by the locality-number; for example: Glam. 36 SW λ 4 designates locality 4 in the 6-inch sheet Glamorgan 36 SW. These descriptive symbols are quoted in this section of the paper, and a majority of them are marked upon the maps (Pls. XV & XVI) which illustrate the paper.

(A) Lower Limestone Shales.

As compared with members of the Main Limestone, the beds constituting the Lower Limestone Shales suffer little change of character when traced through the district here dealt with. The only notable variation is an increasing development of shale in proportion to limestone in the lower beds, when followed from east to west. But the strata undergo a steady expansion in thickness south-westwards from the Ebbw valley to the Taff valley, and the expansion is apparently maintained along their outcrop west of the Taff. Between Risca and Tongwynlais, the thickness of the Lower Limestone Shales increases from about 125 to 260 feet; near Miskin it probably exceeds 300 feet, although a partial masking of the beds by Glacial gravel renders this estimate uncertain; farther west, the drift-cover prevents any determination of thickness.

No section in the district here described exposes the junction of the Lower Limestone Shales with the Old Red Sandstone, although a band of calcareous grit which is the lowest bed exposed in a stream-section below Coed-y-Mochyn, in the Ebbw valley, marks the approximate, if not the precise, base of the Carboniferous (fig. 5, p. 127). But there is no reason to doubt the conformable relation of the two formations.

East of the Taff, the characters of the Lower Limestone Shales are well displayed in fairly numerous sections; west of the Taff, the beds are extensively covered by drift, and exposures are less satisfactory. The development east of the Taff is, therefore, described first.

East of the Taff.

A twofold division of the Lower Limestone Shales, on lithological grounds, was established by Dr. A. Strahan in this outcrop, and represented upon the Geological Survey map.[1] Our own observations lead us to recognize three divisions.

Lower Limestone Shales between the Ebbw and the Taff.

Geological Survey.	Present Classification.	
Shales with thin bands and nodules of limestone.	3. Shales with thin limestones. 50 to 100 feet.	K_2. Subzone of *Spiriferina octoplicata* (J. de C. Sowerby) mut. β Vaughan.
Crinoidal limestone, often oolitic. ('Lower Limestone.')	2. Crinoidal limestone and oolite. 45 to 100 feet.	K_1 or K_2.
	1. Limestones and shales. 30 to (?) 60 feet.	K_1.—Subzone of *Productus bassus* Vaughan.

Our lower division (1) consists mainly of limestone in the Ebbw valley, but includes almost as much shale as limestone in the Taff valley. A partial establishment of *Modiola*-phase conditions is indicated by several features of this lower group, namely, seams of calcite-mudstone with *Serpula*, limestones of *a*-type,[2] and limestones with a mixed fauna of crinoids, brachiopods, ostracods, and thin-shelled lamellibranchs.

The faunas of our lower and upper divisions (1 & 3) warrant the reference of these two groups to K_1 and K_2, respectively, but the scanty fauna of the middle group of limestones (2) affords no grounds for correlation with one subzone rather than the other. It is interesting to note, in this connexion, that both in Gower and in Pembrokeshire a band of oolitic limestone affords the best boundary between K_1 and K_2.[3]

Along much of the outcrop between the Ebbw and the Taff the unequal resistance to denudation of the limestones forming the middle division of the Lower Limestone Shales, and the shales of the upper division, is strikingly expressed in the surface relief. The limestones give rise to a low escarpment-ridge, separated from

[1] Newport Memoir, 2nd ed. p. 19, and Newport sheet.

[2] That is, limestones consisting essentially of crinoid-ossicles and bryozoa, broken and rounded by rolling, reddened with hæmatite, and cemented by clear granular calcite. On the character and significance of such limestones, see E. E. L. Dixon, Gower paper, p. 515.

[3] E. E. L. Dixon, Gower paper, pp. 497–98, and 'The Country around Haverfordwest' Mem. Geol. Surv. 1914, pp. 135–37.

the dominating escarpment of the Main Limestone by a narrow, level or gently sloping, grassy platform which marks the outcrop of the shales. This characteristic landscape feature is well marked on the eastern side of the Rhymney valley, where the ruins of Castell Meredydd stand on the limestone-scarp, and it is conspicuously developed almost without interruption from the upper part of Cwm Draethen westwards to the valley between Craig Llanishen and Cefn Carnau (see photographs, Pl. XII, and section, fig. 4, p. 120). Near Rhubina and Tongwynlais it is again well marked, and at the entrance to the gorge of the Taff the limestone-scarp affords a commanding site for Castell Côch. In two localities, south of Cefn-On Farm and north of Craig Llanishen, respectively, a clean-cut displacement of the features, the result of dip-faulting, is admirably shown.

1. Limestones and shales.—K_1. Lower part of the Lower Limestone of the Geological Survey.

General lithology.—In the Ebbw valley, thinly-bedded limestones of varied character, usually crinoidal and shelly, often ostracodal, and sometimes gritty, with subordinate shales. In the Taff valley, the development of shale is little inferior to that of limestone. Hæmatitic limestones of a-type, precisely similar to the Bryozoa-Bed of the Avon section, occur in the lower part of the group.

Thickness.—About 30 feet in the Ebbw valley, increasing to 50 or 60 feet in the Taff valley.

Fauna:

Corals and brachiopods:—

Cleistopora cf. *geometrica* Edwards & Haime.

Productus bassus Vaughan.
Chonetes cf. *hardrensis* Phillips.
Chonetes stoddarti Vaughan.
Leptæna analoga (Phillips).
Schellwienella cf. *crenistria* (Phillips).
Orthis michelini L'Éveillé.
Camarotœchia mitcheldeanensis Vaughan.
Spirifer clathratus M'Coy.
Syringothyris cf. *cuspidata* (Martin).
Eumetria carbonaria (Davidson).

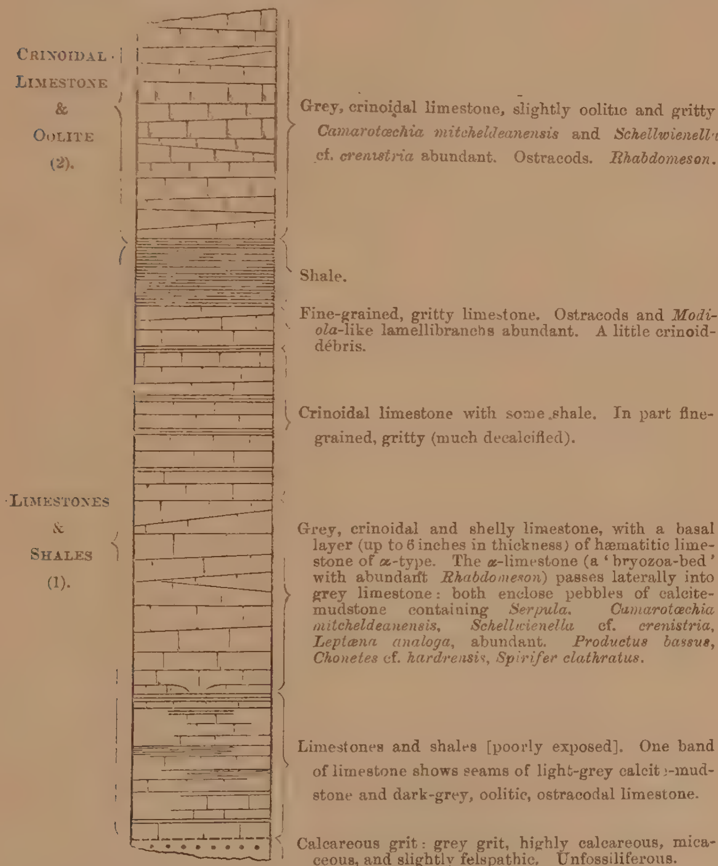
Bryozoa: *Rhabdomeson*, *Fenestella*. Lamellibranchs: *Modiola (?)* sp. Gasteropods: Capulids (*Orthonychia* sp., *Platyceras* sp.) and small turreted forms. Ostracods. Fishes:—*Psephodus* sp.

Good exposures of the beds of this division are found only at the extremities of the outcrop now under consideration.

On the western side of the Ebbw valley, above Pont-y-Mister, the stream which descends from Coed-y-Mochyn exposes, at a little waterfall and in the cascades and banks below it, the section illustrated by fig. 5 (p. 127). Some 250 yards north of this stream-section, a small disused quarry (Mon. 28 SW λ3) affords a second exposure of the same beds, including the calcareous grit at the base, but the section is much grassed over. No shale-bands appear to be developed, and no limestone of a-type has been detected. Some

thinly-bedded limestones in the lower part of the section show seams of smooth calcite-mudstone interbanded with layers of highly oolitic limestone: the oolitic bands are ostracodal and slightly gritty, and contain *Serpula* and algal structures.

Fig. 5.—*Section of the lower part of the Lower Limestone Shales, stream below Coed-y-Mochyn, western side of the Ebbw valley, above Pont-y-Mister (Mon. 28 S.W. N 1). (Vertical scale: 1 inch=10 feet.)*



At Tongwynlais, in the Taff valley, an excavation on the hillside 200 yards east-north-east of the church exposes beds near the base of the group, while a cutting on the Cardiff Railway, at the northern end of the village, traverses the upper beds and exposes their junction with the overlying crinoidal limestones.

The hillside excavation (Glam. 37 SW λ3), in the southern limb of the Tongwynlais syncline, yields the following section:—

2. Green-grey shales: upper part with many thin layers of fine-grained, highly gritty limestone yielding ostracods and brachiopods. The limestone-layers extensively decalcified to a fine, ferruginous sand . . . . to top of section 6 feet.

1. Crinoidal limestones: grey limestones; but at the top, a band of hæmatitic limestone of α-type, up to 10 inches in thickness, and at the base, limestone of the same type, with partings of green shale, seen for 2 feet. Abundant brachiopods (*Productus bassus*, *Chonetes* cf. *hardrensis*, *Leptæna analoga*, *Camarotœchia mitcheldeanensis*, etc.) . . . to base of section 12 feet.

The railway-cutting (Glam. 37 SW λ4) lies in the northern limb of the syncline. It extends southwards from Castell-Côch Tunnel, and traverses a considerable portion of the Lower Limestone Shales. For the most part it lies in the middle group of crinoidal limestone and oolite, but at the northern end it exposes the underlying limestones and shales to a thickness of about 20 feet. These latter beds are highly fossiliferous, yielding all the types of our faunal list, above. *Chonetes* cf. *hardrensis* teems in many bands of limestone. *Productus bassus* is abundant, *Chonetes stoddarti* rare. *Cleistopora* cf. *geometrica* occurs in the shaly cappings of some limestone-bands. The strata comprise limestones and shales interbanded in lenticular fashion, and a considerable development of argillaceous limestone. The shales, grey to black, calcareous and micaceous, occasionally contain numerous ostracods or *Fenestella*, with a few lamellibranchs or small *Chonetes*. The limestones are predominantly dark-grey shelly rocks, with an abundance of brachiopods and ostracods, though seldom conspicuously crinoidal. But this shelly type of limestone is intimately interbanded with very fine-grained, poorly fossiliferous limestone, sometimes smooth and splintery, sometimes laminated and gritty.

These sections in the Taff valley exhibit a development of shale equal or nearly equal in amount to limestone, a considerable change from the character of the group in the Ebbw valley. Limestone of α-type is also developed in larger amount, but evidently at the same horizon. In the neighbourhood of Tongwynlais, moreover, the limestones of α-type have undergone some secondary enrichment in hæmatite, and this has led to more than one trial of the beds for iron-ore. Excellent specimens for the study of these rocks may be obtained, either from the excavation at Tongwynlais (Glam. 37 SW λ3) described above, or from the spoil-heap of an old level north of Rhubina (Glam. 37 SW λ11), mentioned in the Geological Survey memoir.[1] Specimens E 2465 & E 2466 of the Geological Survey collection were obtained from the latter locality. E 2465, illustrated by a microphotograph in Plate, fig. 1, of the memoir, possesses a matrix of clear, granular calcite, comparatively free from hæmatite: in E 2466, on the other hand, the matrix has suffered much ferrification. In

[1] Newport Memoir, 2nd ed. p. 24.

the Rhubina spoil-heap, as in the stream-section in the Ebbw valley (Mon. 28 SW λ1), the *a*-limestone often encloses pebbles of calcite-mudstone (containing *Serpula*) formed by the churning-up of contemporaneous deposits, an indication of current-action that is in keeping with the rolled character of the organic remains.

2. Crinoidal limestone and oolite—K_1 or K_2. Upper and major part of the Lower Limestone of the Geological Survey.

General lithology.—Non-oolitic or slightly-oolitic crinoidal limestone, and oolite which is, as a rule, crinoidal. In the east (Ebbw valley), the development of oolite is subordinate and apparently sporadic: in the west (Taff valley) oolite forms the upper and larger part of the group. Dolomitization is frequent, and (for the greater part) evidently a subsequent feature.

Thickness.—Between 40 and 50 feet on the western side of the Ebbw valley: increasing south-westwards, to 100 feet or more in the Taff valley at Tongwynlais.

Fauna.—Brachiopods are seldom abundant; the chief forms will be noted in the description of exposures. *Fenestella* and *Rhabdomeson* are occasionally common. Ostracods occur in oolitic bands at the base of the group in some localities.

In the Ebbw valley, the stream-section below Coed-y-Mochyn (Mon. 28 SW λ1) exposes about 12 feet of limestone at the base of the group (fig. 5, p. 127). The rock is richly crinoidal and shelly, and contains *Camarotœchia mitcheldeanensis* in abundance: in thin section, it proves to be slightly oolitic, with a few quartz-grains and occasional ostracods and *Rhabdomeson*. On the hillside 50 yards to the north, an old quarry (Mon. 28 SW λ2) gives an almost complete section of the division. The lowest beds exposed are those of the stream-section, here yielding *Leptæna analoga* and *Schellwienella* cf. *crenistria* in abundance, together with *Syringothyris* cf. *cuspidata*, *Fenestella*, and the fish-tooth *Deltodus gibbus*. For the rest, the beds are crinoidal, occasionally oolitic limestones, generally showing conspicuous current-lamination, and extensively vein-dolomitized. About 330 yards farther north, a small excavation on the hillside above Dan-y-Graig Brickworks shows a white oolite which lies near the top of the group.

On the eastern side of the Rhymney valley north of Machen, good exposures are afforded by the crags and old workings along the scarp which extends east and west of Castell Meredydd. Here the limestones have suffered very extensive dolomitization, but the predominance of crinoidal rock, current-laminated in some beds, and the development of oolite-bands, are clearly seen.

Westwards from the Rhymney valley, to the neighbourhood of Rhubina, the beds are seldom well exposed, although often conspicuous in their effect upon the topography. Whenever seen, they are highly dolomitized limestones, often crinoidal, but otherwise poorly fossiliferous, and as a rule fine-grained. The dolomitization in this portion of the outcrop may be partly contemporaneous. The Geological Survey map (Newport sheet) represents the limestone

group as thinning out immediately south-west of Draethen and reappearing a mile farther up Cwm Draethen. We consider such a thinning-out to be highly improbable, and prefer to regard the outcrop of the limestones as continuous along the steep escarpment slope on the northern side of Cwm Draethen.

The group is well exposed in some old quarries north of Rhubina, and even better displayed in the railway-cutting south of Castell-Côch Tunnel, Tongwynlais. In both localities, dolomitization has affected the beds in slight degree only. The railway-cutting (Glam. 37 SW λ 4) traverses the group from base to summit. The beds dip southwestwards at 35° to 40° throughout most of the section; but, at the southern end, their dip increases to 60° and over in a sharp roll. At the base, red-stained crinoidal limestones succeed sharply the limestones and shales of the underlying division; at the top, grey oolite gives place to deeply iron-stained argillaceous limestone and crinoidal limestone, which alternate in thin bands for 8 to 10 feet before the section is terminated by a bank of Glacial gravel. The total thickness of approximately 100 feet comprises about 35 feet of crinoidal non-oolitic limestone below and 65 feet of crinoidal oolite above: but a grassy gap in the section of the lower beds, equivalent to about 12 feet, may indicate some development of shale. The brachiopods in the limestones include *Schellwienella* cf. *crenistria*, *Camarotœchia mitcheldeanensis*, *Spirifer clathratus*, *Syringothyris* cf. *cuspidata*, and a small *Athyris*: of these, only the two first-named are abundant.

The Tongwynlais railway-section shows a development of the limestone group marked by an unusually clear contrast between non-oolitic limestone below and oolite above, although even there a few seams of coarse oolite are intercalated in the crinoidal limestones and occasional non-oolitic bands occur within the oolite. In the old quarries north of Rhubina, crinoidal limestone and oolite alternate repeatedly throughout the group.

Two disused quarries, lying respectively east and west of Castell Côch, expose the upper beds of the limestone group. Each shows a considerable development of oolite, and each exposes the base of the overlying shale-division, but the sections are much overgrown and difficult of access. In the quarry east of Castell Côch the limestone is much dolomitized.[1]

3. Shales with thin limestones.—K_2.

General lithology. Dark-grey to black shales, with subordinate thinly-bedded limestones. The limestones always richly crinoidal and shelly.

Thickness.—In the Ebbw valley, 50 feet or less; increasing to about 100 feet at Tongwynlais in the Taff valley.

[1] Fig. 4 of the plate in the Newport Memoir, 2nd ed., illustrates a partly-dolomitized oolite from the quarry west of Castell Côch. The selective dolomitization of the ooliths points to vein-dolomitization.

Fauna:

Corals and brachiopods:—

Cleistopora cf. *geometrica* Edwards & Haime.

Productus aff. *bassus* Vaughan.
Pustula subpustulosa Thomas.
Chonetes cf. *hardrensis* Phillips.
Schellwienella cf. *crenistria* (Phillips).

Camarotœchia mitcheldeanensis Vaughan.
Spirifer clathratus M'Coy.
Syringothyris cf. *cuspidata* (Martin).
Spiriferina octoplicata (J. de C. Sowerby), mutation β Vaughan.
Athyris roissyi L'Éveillé.
Eumetria carbonaria (Davidson).

Bryozoa:—*Rhabdomeson*, *Fenestella*. Lamellibranchs:—A small *Modiola*-like species. Ostracods.

Good exposures of the beds are few, and only two sections, now to be described, have yielded any considerable fauna.

In the strike-valley between Craig Llanishen and the western end of Cefn-On, and about 600 yards west of the Caerphilly railway-tunnel, the northern bank and the bed of a stream expose black shales with a few thin lenticular bands of limestone (Glam. 37 SW λ10). These beds lie at the base of the group, and succeed sharply the limestone of the underlying group, which is exposed at one point in the southern bank. The thin limestone-bands, of the usual crinoidal and shelly type, contain irregular patches and distinct pebbles of very fine-grained limestone: they have yielded *Pustula subpustulosa*, *Productus* cf. *bassus*, *Chonetes* cf. *hardrensis*, *Schellwienella* cf. *crenistria*, *Athyris roissyi*, and *Syringothyris* cf. *cuspidata*, the first and last-named being notably common; and they contain ostracods in abundance.

On the eastern side of the Taff gorge, Castell-Côch Quarry (Glam. 37 SW λ5) affords the second section, at the point where a small bluff of thinly-bedded limestones and shales protrudes from the scree of limestone-débris at the southern end of the quarry. These beds, lying about the middle of the group, consist more largely of limestone than of shale. The limestones yield *Cleistopora* and all the other types specified in our faunal list, above. *Productus* aff. *bassus*, *Schellwienella* cf. *crenistria*, *Camarotœchia mitcheldeanensis*, and *Rhabdomeson* sp. are particularly abundant. One band of limestone, rich in crinoid-débris and brachiopods, contains ostracods and a small *Modiola*-like shell in abundance.

Castell-Côch Quarry also exposes the uppermost beds of the group, unfossiliferous micaceous mudstones immediately underlying, and succeeded sharply by, the dolomites that form the base of the Main Limestone. The junction of Lower Limestone Shales and Main Limestone is again exposed at the eastern extremity of the district here described, in the lowest beds of Dan-y-Graig Quarry, Risca. There, however, we find an alternation of hard slightly-dolomitic shale with finely-crystalline dolomite.

West of the Taff.

In the district west of the Taff valley the Lower Limestone Shales are, to a great extent, concealed by Boulder Clay and Glacial gravel, but the three divisions established east of the Taff can be recognized. The development of shale in the lowest division appears to increase considerably as we pass westwards. This phenomenon continues the change already noticed in the outcrop east of the Taff: it was recognized by the officers of the Geological Survey on the evidence of exposures near Bolgoed,[1] west of the Ely valley, and expressed on the Survey map (Bridgend sheet) by the representation of three divisions in the Lower Limestone Shales west of Groes-faen, namely, lower and upper shale-divisions separated by a band of limestone. The thickness of the whole series appears to increase westwards, but the limestones which form the middle member do not contribute to this increase; probably their lowest beds are split up by shales in a westerly direction, and so become merged in the underlying group of shales and limestones.

Between the Taff and the Ely, a distance of about 5 miles, outcrops of the Lower Limestone Shales are practically confined to two strips, each about a mile and a quarter long; one lying south and south-west of Pentyrch, the other extending through Groes-faen to the neighbourhood of Croftau. At Creigiau, a cover of Mesozoic rocks conceals the beds, but elsewhere the masking is due to Glacial drift. The beds do not crop out along the margin of Garth Wood, on the western side of the Taff valley, as represented on the Geological Survey map (Cardiff sheet): they lie buried under drift immediately to the south, and the scarp-face of Garth Wood belongs wholly to the Main Limestone. At Groes-faen, the middle and upper members of the Lower Limestone Shales produce landscape features similar to those which are so conspicuous in the country east of the Taff, but less pronounced. The limestone group gives rise to a low, wooded ridge, to the north of which lies a shallow strike-valley, or a grassy flat, marking the outcrop of the shales. The outcrops and their accompanying features are displaced by dip-faults immediately west of Groes-faen: farther west, the features die out as the beds pass under a covering of drift.

West of the Ely the drift-cover is even more extensive. The beds crop out for a short distance at Caer-gwanaf-isaf, immediately west of the Ely valley and north of Hensol Park, and are seen again over a small area between Ystradowen and Llansannor; between these two localities, their extent is almost entirely conjectural.[2]

1. Limestones and shales.—The lower group is nowhere exposed between the Taff and the Ely. West of the Ely, and

[1] Bridgend Memoir, p. 9.
[2] *Ibid.* pp. 7 & 9, and Bridgend map, drift edition.

north of Hensol Park, it is represented by shales exposed in a well and in an adjacent gully 200 yards north-east of Bolgoed Farm. These beds have yielded no fossils.

2. Crinoidal limestone and oolite.—The outcrop of the middle group is marked by many disused quarries, and the exposures indicate a development closely similar to that observed at Tongwynlais: namely, lower beds of richly crinoidal limestone, stained red as a rule, and upper beds of oolite, occasionally vein-dolomitized and iron-stained but usually fresh. The oolite, in a fresh condition, is at present worked in a quarry 100 yards north-east of Maesmawr Farm, east of Groes-faen. A quarry situated immediately west of Caer-gwanaf-isaf (Glam. 42 NW λ4) exposes the topmost beds of the oolite, with some intercalation of crinoidal limestone, overlain by shales. In the outcrop south-east of Llansannor, where the oolite has been quarried at Pen-cyrn and at Newton Farm, it is found to be highly crinoidal, and to pass up into thinly-bedded, argillaceous limestone.

As in the outcrop east of the Taff, the brachiopod-fauna of these limestones is poor. *Schellwienella* cf. *crenistria* is the only abundant form, but *Chonetes* cf. *hardrensis*, *Camarotœchia mitcheldeanensis*, and *Spirifer clathratus* have been recorded at several localities, including the above-mentioned quarry at Caer-gwanaf-isaf.

3. Shales with thin limestones.—The beds of the upper group are seldom exposed. Two exposures, however, have yielded a rich fauna practically identical with that of the same division east of the Taff. These are a small quarry (Glam. 42 NW λ23) lying midway between Groes-faen and Brofiscin Quarry, and a stream-section (Glam. 42 NW λ22) situated 150 yards south-west of Pantaquesta Farm, north of Hensol Park. The former exposes beds very near the top of the Lower Limestone Shales, while the latter reveals a lower horizon in the group: in each case the beds are shales with thin limestones, the shales apparently barren, the limestones crinoidal and shelly. The following brachiopods have been recorded at both localities:—

Productus aff. *bassus*.
Productus burlingtonensis.
Pustula subpustulosa.
Chonetes cf. *hardrensis*.
Schellwienella cf. *crenistria*.
Camarotœchia mitcheldeanensis.
Spirifer clathratus.
Syringothyris cf. *cuspidata*.
Athyris roissyi.
Eumetria carbonaria.

In addition to the species enumerated above, the Groes-faen exposure has yielded *Spiriferina octoplicata*, and the section near Pantaquesta Farm, *Cleistopora* cf. *geometrica*. Ostracods, small gasteropods (Capulids), and *Rhabdomeson* occur at both localities.

East of Llansannor, the Geological Survey map represents a small outlier of the Main Limestone, unaccompanied by faulting. Our mapping shows this area of Main Limestone as a tongue,

continuous with the outcrop of Limestone on the north, but faulted against Lower Limestone Shales on the east. The fault, running south-westwards past Pen-cyrn to Pen-y-lan, cuts out almost the whole of the shales with thin limestones at Pen-cyrn. This would account for the apparent greatly-reduced thickness of the shale group (estimated from width of outcrop) at the latter place, mentioned in the Geological Survey memoir.[1]

About 650 yards east of Llansannor Church, black shales and thinly-bedded argillaceous limestones are exposed in a small excavation and in the lane adjacent to it (Glam. 41 SE λ7). The limestones, often ostracodal, contain many brachiopods, including *Productus* aff. *bassus* and *Spiriferina octoplicata*. The shales yield small *Modiola*-like lamellibranchs.

(B) Main Limestone.

The sequence of zones is most nearly complete in the west of the district, and there it can be recognized in detail. The area west of the river Taff will, therefore, be described first.

West of the Taff.

Zaphrentis Zone and Lower *Caninia* Zone: Z & C_1.

The sequence Z–C_1 is represented by one colour on our map (Pl. XV) because evidence for a satisfactory delimitation of Z and C_1 is not forthcoming.

In the westernmost part of the outcrop the succession is mainly one of undolomitized crinoidal limestones and oolites, contemporaneous dolomitization being practically confined to two horizons, namely, a lower level, in Z, and an upper level (the *Laminosa* Dolomite) in C_1. Eastwards, dolomitization affects a steadily-increasing portion of the sequence until, in the Taff valley, it has produced an unbroken succession of dolomites.

The following table summarizes the sequence in the outcrop between Miskin and Groes-faen, where the beds are, on the whole, best exposed. No precise limits can be assigned to the several subdivisions; and the thicknesses stated, estimated in most cases from dip and outcrop, are only rough approximations:—

Z & C_1 between Miskin and Groes-faen.

		Feet.
C_1	8. *Caninia* Oolite: pale-grey oolite, thickly-bedded to massive. 7. *Laminosa* Dolomite: finely-crystalline dolomite, crinoidal in part.	340
	6. Crinoidal limestones, dolomitic at the base. A little chert. Abundant corals and brachiopods (γ C_1).	180
	Oolite: crinoidal, current-bedded	20
Z	5. Dolomites and dolomitic limestones, crinoidal in part. A little chert near the base.	210
	4. Crinoidal limestones, with argillaceous layers, chert, and beekite. *Zaphrentis delanouei* and abundant brachiopods (Z_1).	35

[1] Bridgend Memoir, p. 11.

The top of the *Caninia* Oolite, which is the generally-recognized dividing line between C_1 and C_2,[1] thus marks the upper limit of the series $Z-C_1$. This constitutes the boundary between Lower Avonian and Upper Avonian, as established by Mr. E. E. L. Dixon on stratigraphical grounds. It marks the culmination of a shallowing movement in the South-Western Province which produced the widespread development of a *Modiola* phase at the base of C_2, and even led to emergence and consequent unconformity in some areas.[2] The significant *Modiola* phase has been recognized at Miskin in the area here described, where it succeeds the *Caninia* Oolite sharply (p. 140).

4. Crinoidal limestones: Z_1.—These beds, forming the base of the Main Limestone, are essentially dark-grey or black crinoidal limestones, thinly bedded and flaggy, with argillaceous bands and patches. A current-bedded rock, consisting of richly-crinoidal bands separated by lenticles and streaks of compact argillaceous limestone, is often developed. The development of chert in nodular or banded forms and the beekitization of fossils are frequent, and silicification sometimes results in the formation of small nodules of milk-white banded chalcedony.

The beds are exposed at many points between Penlline and the neighbourhood of Pentyrch: the chief exposures are specified in the faunal list, below. Eastwards from Creigiau, dolomitization develops rapidly: but, even in their highly-dolomitized condition, the beds are readily identified by their general characters and their abundant brachiopods. Thin seams crowded with *Chonetes* cf. *hardrensis* are especially characteristic.

Fauna. Genera and species of corals and brachiopods.	Locality.					
	1.	2.	3.	4.	5.	6.
Zaphrentis delanouei Edwards & Haime, Carruthers	...	.	.	.	..	×
Pustula subpustulosa Thomas	...	...	...	...	×	..
Productus burlingtonensis Hall, Vaughan	×	...	...	×	...	..
Productus cf. *concinnus* Sowerby	...	×	...	...	...	...
Chonetes cf. *hardrensis* Phillips	×A	×A	×A	×A	×	×A
Leptæna analoga (Phillips)	×	...	...	...	...	×A
Schellwienella cf. *crenistria* (Phillips)	×A	×	×A	×A	×A	×A
Orthis michelini L'Éveillé	...	×C	...	...	×C	×
Camarotœchia mitcheldeanensis Vaughan	×	...	×A	×	×	×A
Spirifer clathratus M'Coy	×A	×A	×A	×A	×A	×A
Syringothyris cf. *cuspidata* (Martin)	×	×C	...	×C	×	×C
Athyris glabristria (Phillips), Vaughan	...	×	..	..	...	...

A=Abundant. C=Common.

[1] A. Vaughan, Q. J. G. S. vol. lxxi (1915–16) folding table facing p. 32.

[2] Gower paper, p. 542. See also 'The Country around Carmarthen' Mem. Geol. Surv. 1909, pp. 81–82, and 'The Country around Haverfordwest' *ibid.* 1914, pp. 127–28.

1. Quarry (Glam. 41 SW λ 1), on the west side of the road, 400 yards north of Penlline Church.
2. Exposures (Glam. 41 SE λ 2), a little west of Coed Pen-cyrn, east of Llansannor.
3. Crags (Glam. 41 SE λ 3), 200 to 250 yards west of New Barn, east of Llansannor.
4. Exposure (Glam. 42 NW λ 14), 700 yards east of the cross-roads, Miskin.
5. Old Quarry (Glam. 42 NE λ 2), 100 yards east-north-east of Craig Channel, Pant-y-gored.
6. Old Quarries (Glam. 42 NE λ 5), 700 yards south-east of Pentyrch Church.

5. Dolomites and dolomitic limestones: Z.—From Miskin eastwards, this is essentially a series of grey finely crystalline dolomites, with numerous small nests of calcite and dolomite. Chert is developed sporadically near the base. Crinoid-ossicles are often abundant, but brachiopods are rare. *Spirifer clathratus* and *Schellwienella* cf. *crenistria* are the only species of the latter group recorded, unless the fossiliferous band of Ty-nant Quarry (p. 138) is included in this division.

The beds are poorly exposed. Two sections near Miskin, and one east of Creigiau, expose the base of the group and the passage into the underlying crinoidal limestones: these are (1) crags (Glam. 42 NW λ 14), representing old workings, 700 yards east of the cross-roads at Miskin, (2) a small quarry midway between these crags and the cross-roads, and (3) old quarries (Glam. 42 NE λ 5) 700 yards south-east of Pentyrch Church. Ty-nant Quarry, in the Taff valley, affords the only good exposure of the upper beds of the group. A fossiliferous band in this quarry should perhaps be included in this group, that is, in Z, rather than in the *Caninia* Zone (see p. 138).

In the drift-covered area west of Miskin, exposures are few, and little is known about the group. The lower part retains its dolomitic character as far west as the ground north of Ystradowen; but, farther west, dolomitization at this level seems to diminish. The lower portion of a thick oolite which is developed north of Llansannor and Penlline appears to represent the upper beds of this group in the extreme west. This oolite is well seen in a quarry (Glam. 41 SE λ 4) at New Barn, 800 yards east of Llansannor Church: it is there a dark-grey rock containing *Spirifer clathratus* and a few other brachiopods.

6. Crinoidal limestones, etc.: γC_1.—This division is a series of thinly-bedded, richly-crinoidal, grey or black limestones, with a considerable development of poorly-crinoidal argillaceous bands, usually buff-coloured. An irregular development of black argillaceous streaks, accompanied by contemporaneous brecciation and evidently due to current-action, is not uncommon. Many of the crinoidal beds are very rich in brachiopods and corals, together with gasteropods and bryozoa. Nodular chert is developed occasionally, in small amount.

The group is well-exposed in three quarries between Groes-faen and Miskin, and farther west in two quarries, near Ystradowen and Llansannor respectively (see faunal list, below). In Brofiscin Quarry (Glam. 42 NW λ 16), north of Groes-faen, finely-crystalline blue-grey dolomites form a band, about 12 feet thick, at the base of the crinoidal limestones, and are underlain by a thickly-bedded grey oolite, seen to a thickness of about 20 feet. In an old quarry (Glam. 42 NW λ 15) 400 yards east of Miskin, the base of the crinoidal limestones is highly dolomitic. Both in an old quarry (Glam. 42 NW λ 17) north of Croftau and in a quarry (Glam. 41 SE λ 1) east of Ash Hall, Ystradowen, the crinoidal limestones are seen to pass up into the *Laminosa* Dolomite.

Fauna. Genera and species of corals and brachiopods.	Locality.				
	1.	2.	3.	4.	5.
Amplexus coralloides Sowerby	...	×	...	...	...
Zaphrentis omaliusi Edwards & Haime, Carruthers, including *Z. densa* Carruthers	×	×	×	×	...
Zaphrentis sp. nov.	×	×	×	...	×
Caninia aff. *cornucopiæ* Michelin, Carruthers	...	×	...	...	×
Clisiophyllid	...	×	×	...	×
Pustula aff. *subpustulosa* Thomas	×	×	×	...	×
Productus cf. *concinnus* Sowerby	...	×	...	...	×
Productus aff. *cora* D'Orbigny	...	×	...	×	×
Chonetes cf. *hardrensis* Phillips	...	×	×	×	×
Chonetes cf. *buchiana* De Koninck	...	×	×	×	×
Papilionaceous *Chonetes*	×	×	×	...	×
Leptæna analoga (Phillips)	...	...	×	...	×
Schellwienella cf. *crenistria* (Phillips)	×	×	×	×	×
Orthis michelini L'Éveillé	×	×	×	...	×
Orthis resupinata (Martin)	×	×	×	×	×
Spirifer clathratus M'Coy	×	×	×	×	×
Syringothyris cf. *cuspidata* (Martin)	×	×	×	×	×
Spiriferina cf. *laminosa* M'Coy	...	×	×	×	×
Reticularia aff. *lineata* (Martin), Vaughan	×	×	...	...	×
Athyris glabristria (Phillips), Vaughan	...	×	×	...	×

1. Old Quarry (Glam. 41 SE λ 5), near the western side of King Coed, north-east of Llansannor.
2. Quarry (Glam. 41 SE λ 1), 550 yards east of Ash Hall, Ystradowen.
3. Old Quarry (Glam. 42 NW λ 15), a quarter of a mile east of Miskin.
4. Old Quarry (Glam. 42 NW λ 17), 150 yards north of Croftau.
5. Brofiscin Quarry (Glam. 42 NW λ 16), 300 yards north of Groes-faen.

Gasteropods are usually abundant: the forms include *Euomphalus* (particularly abundant at Ystradowen), *Bellerophon*, and a Capulid. Bryozoa, including *Fenestella*, Monticuliporids, and Stenoporids, are sometimes abundant.

While the fauna admits of no doubt in assigning the beds to γC_1, a separate recognition of Horizon γ is not possible. Specially characteristic features are the occurrence of *Caninia* aff. *cornucopiæ* and the abundance of *Zaphrentis densa*, *Orthis michelini*, and *Spiriferina* cf. *laminosa*.

Large vesicular Caninids (*Caninia patula*, *C. cylindrica*) are a conspicuous feature of the fauna at this level in the Avonian generally. No specifically determinable corals of this type have been found in our district; but the upper beds of the crinoidal limestones contain many patches of coarsely-crystalline calcite, the form and size of which suggest large Caninids, and in some of these patches remnants of thickened septa have been observed.

Eastwards from Groes-faen, the crinoidal limestones of this group pass rapidly into dolomites, and dolomitization has usually obliterated the fossils, with the exception of the highly-resistant crinoid-ossicles. Immediately east of Creigiau, however, a small quarry (Glam. 42 NE λ3), situated 170 yards north-north-west of Craig Channel, exposes crinoidal dolomites, together with some beds of black crinoidal limestone that have suffered only a patchy dolomitization. Corals and brachiopods are numerous throughout the beds of this section: they include *Zaphrentis omaliusi*, *Zaphrentis* sp. nov., *Orthis resupinata*, and *Spiriferina* cf. *laminosa*, a fauna which seems to warrant the reference of the beds to γC_1.

In the dolomite-series of the Taff valley, the crinoidal dolomites that form the upper beds of Ty-nant Quarry (Glam. 37 SW λ1) include a richly-fossiliferous band which represents either the base of our γC_1 group, or a slightly-lower horizon, in Z_2. This band consists of red completely-crystalline dolomite, in which all the brachiopods and corals, and many of the crinoid-ossicles, are represented by casts or moulds. The following corals and brachiopods occur:—

Zaphrentis konincki; common.
Schellwienella cf. *crenistria*; abundant.
Orthis michelini.
Orthis resupinata; very abundant.
Camarotœchia mitcheldeanensis; rare.
Spirifer clathratus; common.
Syringothyris cf. *cuspidata*.
Spiriferina cf. *laminosa*; abundant.

7 & 8. *Laminosa* Dolomite and *Caninia* Oolite: C_1 (upper part).—These two divisions have been traced from the western side of the Dawen valley, north of Penlline, as far east as the neighbourhood of Groes-faen, but it is only between the latter place and Miskin that they are well displayed.

Between Miskin and Groes-faen, the collective thickness of the *Laminosa* Dolomite and the *Caninia* Oolite probably remains fairly constant at about 340 feet. Each division has been proved to a thickness of over 100 feet, but it has been impossible to determine even approximately a boundary between the two.

Laminosa Dolomite.—Dark-grey or blue-grey finely-crystalline dolomites, slightly crinoidal towards the base, but otherwise apparently unfossiliferous. In the lowest beds, however, rounded patches of coarsely-crystalline calcite possibly represent the re-crystallized infillings of cavities in fossils.[1]

The face of an old quarry (Glam. 42 NW λ 17) situated 150 yards north of Croftau shows the base of the *Laminosa* Dolomite in contact with the underlying crinoidal limestones; and a cutting which runs northwards from the quarry exposes fully 100 feet of dolomite.

The following are the chief exposures of the *Laminosa* Dolomite, enumerated in order from west to east:—

Old Quarry (Glam. 41 SW λ 4), beside the road at Ty'n-y-graig, on the western side of the Dawen valley, north of Craig Penlline.

Old Quarry, 150 yards south of St. Ann's Chapel, south of Brynsaddler.

Old Quarry (Glam. 42 NW λ 17), 150 yards north of Croftau; and cutting extending northwards from the quarry.

Exposure on the northern side of Brofiscin Quarry, north of Groes-faen.

Caninia Oolite.—Essentially, pale-grey thickly-bedded oolite, often with imperfect stratification. The oolitic structure is variably coarse or fine. The rock is typically foraminiferal. Current-bedding is frequent, and many current-bedded portions give evidence of contemporaneous erosion in an abundance of angular or rounded fragments of oolite. Apart from crinoids and foraminifera, fossils are almost confined to an abundance of the brachiopod *Schellwienella* cf. *crenistria*, or the gasteropods *Bellerophon* and *Euomphalus*, in rare bands. *Syringopora* cf. *distans*, *S.* cf. *reticulata*, *Seminula* cf. *ficoides*, and papilionaceous *Chonetes*, occur rarely. In the main mass of the *Caninia* Oolite crinoidal bands are few, but near the top the rock may become highly crinoidal, as seen in a quarry north of Croftau (Glam. 42 NW λ 18). The crinoidal beds at this locality contain papilionaceous *Chonetes*, and have yielded a single corallite of *Lithostrotion martini (?)*.

In an old quarry at the Castell-y-Mynach Arms (Glam. 42 NW λ 20), near Croftau, the *Modiola* phase of C_2 is seen resting upon an eroded surface of the *Caninia* Oolite (see p. 141).

The following are the chief exposures of the *Caninia* Oolite, named in order from west to east:—

Old Quarry (Glam. 41 SW λ 5), at the south-eastern end of Coed Mansel, on the western side of the Dawen valley, north of Craig Penlline.

Exposures in woods (Graig), 750 yards north-north-east of Llansannor Church.

Old Quarry (Glam. 41 NE λ 8), a quarter of a mile south of Brynsaddler.

Quarry (Glam. 42 NW λ 8), 200 yards west of Caer-gwanaf-uchaf, on the western side of the Ely valley near Miskin.

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[1] Compare E. E. L. Dixon, Gower paper, p. 483.

Old Quarry (Glam. 42 NW λ 21), beside the road 400 yards north-north-east of the cross-roads at Miskin.

Old Quarry (Glam. 42 NW λ 20), at the Castell-y-Mynach Arms, west-north-west of Croftau.

Quarry (Glam. 42 NW λ 18), 350 yards north of Croftau.

Old Quarry, 300 yards north-east of Brofiscin Quarry, near Groes-faen.

In the last-named exposure, the *Caninia* Oolite has been traced a little to the east of Groes-faen. Neither the *Laminosa* Dolomite nor the *Caninia* Oolite has been recognized farther east. Both become merged in the series of dolomites which constitutes the whole of C_1 in the Taff valley.[1]

Upper *Caninia* Zone: $C_2 + S_1$.[2]

The series, $C_2 + S_1$, includes all the beds between the *Caninia* Oolite below and the Main *Seminula* Zone (S_2) above. Its upper limit, the base of S_2, is defined by the appearance of *Cyrtina carbonaria*. Essentially, this is a series of standard limestones in which C_2 and S_1 are faunally continuous; but a *Modiola* phase is found to form the base at the only locality where that horizon is exposed.

Exposures east and west of the Ely River, in the neighbourhood of Miskin, enable us to establish the following general succession:—

[$C_2 + S_1$] in the neighbourhood of Miskin.

		Feet.
$C_2 - S_1$ (= Horizon δ).	12. Thinly-bedded limestones of very varied character, including crinoidal-shelly limestones, oolites, and black calcite-mudstones. *Lithostrotion martini* abundant. 11. Thickly-bedded, grey, crinoidal oolite, in part current-bedded and contemporaneously brecciated. Occasional bands of dark, thinly-bedded, gasteropod-limestone. *Cyathophyllum* ϕ abundant.	150
Lower C_2.	10. Thinly-bedded, dark, crinoidal limestones. Beds of dolomitic limestone or finely-crystalline dolomite, and partings of shale or shaly limestone occur, but are subordinate. 9. *Modiola* phase: a varied group, comprising calcite-mudstone, dolomite, oolite, breccia, etc. Over 16 feet thick (direct measurement).	200

9. *Modiola* phase.—This is exposed in an old quarry behind the Castell-y-Mynach Arms, between Croftau and Miskin, where it forms the top of the quarry-face and is seen to rest upon an uneven surface of the *Caninia* Oolite. The top of the phase is not seen. The details of the section are as follows:—

[1] But see footnote on p. 143.

[2] Equivalent to the Upper *Syringothyris* Zone (C_2) and the Lower *Seminula* Zone (S_1).

Modiola phase at the base of C_2.—Old Quarry at the Castell-y-Mynach Arms, near Croftau (Glam. 42 NW λ 20).

	Feet	inches.
7. Calcite-mudstone: much like that of (5)........seen for	2	0
6. Oolitic limestone: dark grey to black. Athyrids of Seminuloid form fairly numerous	0	6
5. Calcite-mudstones: dark grey to black, weathering to a white skin. Thickly-bedded, with partings of black shale and platy calcite-mudstone	8	0
4. Dolomite: thinly-bedded, and very fine-grained (in thin section under the microscope, irregular patches of exceedingly fine-grained dolomite enclosed by dolomite of less fine grain)..	2	0
3. Limestone-breccia: fragments of oolite and of calcite-mudstone, similar in character to the nodules of (1); matrix of fine-grained grey limestone. The fragments more numerous in the lower than in the upper part	1	6
2. Red marl	0	2
1. Rubbly limestone and red marl, loosely coherent. The limestone-nodules are rounded fragments of (*a*) dark oolite, such as occurs in the underlying *Caninia* Oolite, and (*b*) dark calcite-mudstone, such as forms (5) and (7), sometimes structureless, sometimes exhibiting wavy or contorted lamination. The red marly matrix is formed largely of ooliths, which were probably derived from fragments of oolite by gentle attrition. (Resting sharply upon, and filling up inequalities in the surface of, the *Caninia* Oolite)	2	0
Total thickness of *Modiola* phase seen.........	16	2

This development of the C_2 *Modiola* phase resembles very closely that in the eastern district of Gower, described by Mr. E. E. L. Dixon.[1]

10, 11, & 12. Standard limestones.—The general lithology has been described in the table on p. 140. The faunal characteristics may be defined by means of a tabular list of fossils, supplemented by notes on salient features.

A large element of faunal continuity throughout the series is evident from the table (p. 142). On the one hand, however, several features of Group 10 serve to differentiate this group from the rest of the series, and to characterize it as Lower C_2: such are the abundance of *Seminula* cf. *ambigua*, the comparative scarcity of *Productus corrugato-hemisphericus* and *Cyathophyllum* φ, and the absence or rarity of *Carcinophyllum* and *Lithostrotion*.[2] On the other hand, groups 11 and 12 represent Upper C_2 and S_1, and together constitute Horizon δ as emended by Vaughan,[3] well

[1] Gower paper, pp. 485–86.

[2] Compare the Burrington-Combe section, Mendips; A. Vaughan, Q. J. G. S. vol. lxvii (1911) pp. 368–69.

[3] 'In the South-Western Province, Horizon δ includes Upper C_2 and S_1, that is, from the maximum of *Cyathophyllum* φ to the incoming of *Cyrtina carbonaria*.' A. Vaughan, Q. J. G. S. vol. lxxi (1915–16) p. 18. The base of Horizon δ, and, therefore, the boundary between our groups 10 and 11, is the division-line between Tournaisian and Viséan adopted by Delépine and Vaughan: *ibid.*, folding table facing p. 32.

A=Abundant. R=Rare.	Lower C_2. 10. Crinoidal limestones.	C_2-S_1 (Horizon δ). 11. Grey oolite.	12. Variable thinly-bedded limestones.
Corals:—			
Michelinia grandis M'Coy	×R	×	..
Syringopora cf. *distans* Fischer	×	×	×
Syringopora cf. *reticulata* Goldfuss	×	×	. .
Caninia cylindrica (Scouler), Salée	×	×R	×R
Cyathophyllum ϕ Vaughan	×	×A	×
Lithostrotion martini Edwards & Haime	...	×R	×A
Carcinophyllum mendipense Sibly	...	×	×
Brachiopods:—			
Small pustulose and punctate *Producti*	×	...	...
Productus cf. *concinnus* Sowerby	×	...	...
Productus corrugato-hemisphericus Vaughan (including *Pr.* aff. *cora* D'Orbigny and *Pr.* θ Vaughan)	×	×A	×A
Chonetes cf. *hardrensis* Phillips	×	...	...
Papilionaceous *Chonetes*	×	×A	×A
Chonetes carinata Garwood (=*Ch. destinezi* Vaughan)	×	...	.
Schellwienella cf. *crenistria* (Phillips)	×A	×A	×
Camarophoria isorhyncha (M'Coy)	...	...	×R
Small Rhynchonellids, including *Rhynchonella* cf. *angulata* (Linnæus)	×	...	
Small Spirifers, including *Spirifer* cf. *furcatus* M'Coy	×	×	×
Syringothyris cf. *cuspidata* (Martin)	×	×	...
Spiriferina cf. *laminosa* M'Coy	...	×	...
Seminula cf. *ambigua* (Sowerby)	×A	×	..
Seminula ficoides Vaughan	×	×	×
Athyris cf. *expansa* Davidson, *non* (Phillips)	×A	×	×
Athyris ingens De Koninck	...	...	×R
Reticularia aff. *lineata* (Martin), Vaughan	×	...	...
Gasteropods:—			
Bellerophon	×	×A	×
Euomphalus	×	×	×

characterized in the district here described by the abundance of *Productus corrugato-hemisphericus* and the common occurrence of *Carcinophyllum* throughout, the maximum of *Cyathophyllum* ϕ, and the appearance of abundant *Lithostrotion* in the upper

part. In so far as Upper C_2 and S_1 can be separately distinguished, Group 11, with *Syringothyris* cf. *cuspidata* and abundant *Cyathophyllum* φ, represents Upper C_2; while Group 12, with abundant *Lithostrotion*, represents S_1.

Westwards from the Ely valley, the sequence in the standard limestones of C_2 and S_1, so far as it can be determined, appears to persist to the extremity of our district without substantial modification; but, owing to the absence of exposures, the S_1 limestones of Group 12 have not been traced much more than half-a-mile west of Miskin.

Eastwards from the Ely valley, the crinoidal limestones of Group 10 have not been recognized east of Croftau, but higher beds, still preserving the character of limestones with an abundant standard fauna, are exposed a mile and a half farther east, in Creigiau Quarry. In the distance of 2½ miles from Creigiau Quarry to the Taff, exposures are poor, and throw little light on the lateral change which converts almost the whole of C_2 and S_1 into a nearly-barren series of dolomites in the Taff valley.[1] The characters of the series on the eastern side of the Taff gorge are described on p. 150.

It remains to specify the chief exposures of the standard limestones of C_2 and S_1 in the outcrop west of the Taff. The exposures will be taken in order from west to east, and descriptions confined to a statement of horizon (except where special features of lithology or fauna call for notice).

Old Quarry (Glam. 41 SW λ 2), on the north side of the road 300 yards south-west of Pont-y-Rhŷd, on the western side of the Dawen valley: apparently the base of the grey oolite 11, with the topmost beds of the underlying crinoidal limestones 10.

Crags extending eastwards from the hamlet of City, north of Llansannor, and terminating on the west in a quarry behind the City Inn: the grey oolite 11, highly crinoidal.

Quarry (Glam. 41 NE λ 7), in Coed-y-Fforest, south of Llanharry Station: a good exposure of the crinoidal limestones of Group 10, seen to a thickness of nearly 100 feet. Some shaly partings and dolomitic beds, and some brecciation due to contemporaneous erosion. *Caninia cylindrica* is common, *Michelinia grandis* occurs, and *Chonetes* cf. *hardrensis* is abundant.

Old Quarry at the roadside 450 yards west of the last-named quarry: the grey oolite of group 11.

Old Quarry (Glam. 42 NW λ 10), at the southern end of Coed Gellihir-ganol, between Brynsaddler and Miskin: the junction of crinoidal limestone and oolite, at the top of 10 and base of 11.

[1] [A recent examination of the old workings of the Garth iron-mine has revealed two bands of oolite within the contemporaneous dolomites that underlie the *Seminula* Oolite in Garth Wood. Both these oolite-bands have suffered very extensive subsequent dolomitization. The lower band may represent either the *Caninia* Oolite or some part of C_2. The upper band can be assigned without doubt to C_2+S_1: it is probably identical with the band, shown in our diagram of the Taff's Well and Tongwynlais sequence (vertical sections, fig. 2, p. 119), of which evidence is furnished in C_2+S_1 on the eastern side of the Taff gorge by surviving patches of unaltered oolite (p. 150).—*T. F. S., July 4th, 1918.*]

Old Quarry (Glam. 42 NW λ 9), north of Ty-isaf, and 500 yards east of the last-named exposure: mainly in the crinoidal limestones of Group 10, but the base of the overlying oolite just appears. The crinoidal limestones contain many dolomitic bands, in one of which casts of *Productus corrugato-hemisphericus* are numerous. The great abundance of *Seminula* cf. *ambigua* in one bed recalls a level in Lower C_2 of Burrington Combe, Mendips.

Old Quarry (Glam. 42 NW λ 11), in Coed Gellihir-uchaf, north of λ 10: the westernmost exposure of the S_1 beds of Group 12. Very variable crinoidal and oolitic limestones in frequent alternation, with lateral change from one type of rock to the other. The uppermost beds are extraordinarily fossiliferous, and formed largely by masses of *Lithostrotion martini*: they yield *Carcinophyllum mendipense*, *Camarophoria isorhyncha*, and *Athyris ingens*, an assemblage which recalls the 'Milton-Road level' in S_1 of Weston-super-Mare and the Mendips.[1]

Quarry (Glam. 42 NW λ 2), a quarter of a mile north of Miskin: this quarry illustrates the sequence of the three groups recognized in the standard limestones of C_2 and S_1 (see photograph, Pl. XIV). Extending for more than 200 yards along the strike, it affords an admirable exposure of the beds. The section includes the uppermost beds of the crinoidal limestones of Group 10, seen to a thickness of 20 to 30 feet; the whole of the grey oolite of Group 11, 40 to 50 feet thick; and about 25 feet of beds belonging to Group 12. The beds assigned to the top of Group 10 are dark-grey crinoidal limestones, with shale-partings, yielding *Cyathophyllum* φ among other fossils. The grey oolite 11, and the thinly-bedded limestones of Group 12, exhibit their typical lithology and fauna (described on pp. 140-43). More than half-way up in the oolite is a band of thinly-bedded, black, gasteropod-limestone, with abundant *Bellerophon*: this is conspicuous in the photograph (Pl. XIV) as a projecting rib. Current-bedding and contemporaneous brecciation are particularly conspicuous in the uppermost part of the oolite. A thin smut-band,[2] of carbonaceous shaly matter, up to 8 inches in thickness, rests upon an apparently-eroded surface of the oolite, and separates this from the thinly-bedded limestones of Group 12. These latter beds include a band of pink marl with distorted lamination, and a thick bed of marly limestone.

Quarry (Glam. 42 NW λ 1), lying immediately west of the last-named: the grey oolite and the base of Group 12.

Old Quarry 100 yards north of the Castell-y-Mynach Arms, near Croftau: a section in the crinoidal limestones of Group 10.

Small excavation (Glam. 42 NW λ 19), 300 yards north-east of the Castell-y-Mynach Arms, near Croftau: crinoidal limestones of Group 10, vein-dolomitized in part, and including a 12-inch band of dolomite-mudstone. *Chonetes carinata* occurs, in association with *Syringothyris* cf. *cuspidata*.

Creigiau Quarry (Glam. 42 NE λ 4): the great thickness of oolites and oolitic limestones here exposed probably belongs mainly to C_2 - S_1, representing Group 12 of the Miskin sequence. The lower beds yield *Lithostrotion martini* (abundant) and a large Caninid (rare) among many other fossils. Complex faulting and extensive vein-dolomitization have affected the highest beds of the quarry, which probably represent the base of S_2.

Main *Seminula* Zone: S_2.

The appearance of *Cyrtina carbonaria* marks the base, and the occurrence of the *Dibunophyllum* fauna defines the top, of S_2. It

[1] T. F. Sibly, Q. J. G. S. vol. lxi (1905) p. 560, and A. Vaughan, *ibid.* vol. lxvii (1911) p. 370.

[2] Compare the smut-beds in the Lower *Dibunophyllum* Zone of Gower: R. H. Tiddeman, 'The Country around Swansea' Mem. Geol. Surv. 1907, pp. 10, 11; also E. E. L. Dixon, Gower paper, p. 490.

is only in the outcrop west of the Ely, however, that the overlying beds of the *Dibunophyllum* Zone occur. East of the Ely, the top of S_2 is overstepped by the Millstone Grit.

The main *Seminula* Zone maintains a constant character from the western end of the district here described as far as the river Taff, except for the fact that its basal beds have become dolomites in the Taff valley.

Lithology.—Two divisions can be recognized, but they probably pass insensibly one into the other[1] :—

14. *Modiola* phase with much standard limestone. Extraordinarily varied in details of lithology. *Modiola*-phase deposits,[2] namely, calcite-mudstones including white-weathering 'chinastone-limestones' with conchoidal fracture, and limestones with pisolitic and pseudo-concretionary structures, alternate repeatedly with, and pass into, standard limestones which are essentially oolitic, shelly, and crinoidal. Bands of fairly-pure oolite are not infrequent. Pisolitic structures are abundantly developed: they are often, but not invariably, accompanied by brecciation due to contemporaneous erosion.

13. *Seminula* Oolite: essentially, grey oolites and oolitic limestones of standard type, but including some very subordinate *Modiola*-phase deposits resembling those of the overlying group. Current-bedding and the development of contemporaneous brecciation are occasional.

Thickness.—Between 500 and 600 feet, of which the *Modiola* phase forms less than 200 feet.

Fauna.—Fossils of the standard groups, brachiopods, corals, and crinoids, are quite as abundant and varied in the *Modiola* phase as in the *Seminula* Oolite. They are, however, notably less common in the calcite-mudstones and certain other less fine-grained limestones developed in the *Modiola* phase; in these beds, *Seminula ficoides* is almost the only abundant form. In the *Modiola* phase, the rock-types just mentioned, and also the pisolitic beds with their numerous standard fossils, often contain *Serpula*.

Gasteropods, including *Bellerophon*, *Euomphalus*, and *Loxonema*, are sometimes common.

Corals:—

Alveolites septosus (Fleming), Edwards & Haime.
Syringopora cf. *distans* Fischer.
Syringopora cf. *geniculata* (Phillips), Edwards & Haime.
Lithostrotion martini Edwards & Haime.
Lithostrotion (Nematophyllum) minus, M'Coy.
Carcinophyllum vaughani Salée (*C.* θ Vaughan).

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[1] Compare Mr. Dixon's description of S_2 in the eastern district of Gower; Gower paper, p. 488.

[2] For the general characteristics of the S_2 *Modiola* phase, see E. E. L. Dixon, Gower paper, p. 514.

Brachiopods:—

Papilionaceous *Chonetes*.
Productus corrugato-hemisphericus Vaughan.
Productus hemisphericus J. de C. Sowerby.
Schellwienella cf. *crenistria* (Phillips).
Cyrtina carbonaria M'Coy.
Seminula ficoides Vaughan.
Athyris cf. *expansa* Davidson, *non* (Phillips).

On the whole, corals and brachiopods are not abundant, much of the *Seminula* Oolite being poor in macroscopic organisms. But beds crowded with *Seminula*, *Productus*, or *Chonetes* are fairly frequent. *Lithostrotion martini* is seldom abundant. *Carcinophyllum vaughani* may occur commonly at any level in the zone. *Nematophyllum minus* is only found near the base, while *Alveolites septosus* and a large form of *Productus hemisphericus* become abundant near the top.

Following are notes on the best exposures of the S_2 beds, taken in order from west to east:—

Many exposures of beds in the upper part of S_2 occur in the outcrop from Ruthin to Llanharry: among them are the following:—

Old Quarries (Glam. 41 NW λ 2), immediately east of the Roman Camp, south of Ruthin.

Old Quarries near Gelligarn Castle, in Coed Breigam, about a mile east of Ruthin.

Exposures immediately south and east of Llanharry village:—

Quarry (Glam. 41 NE λ 5), 300 yards south, a little west, of St. Illtyd's Church.

Old Quarry (Glam. 41 NE λ 4), 300 yards east of St. Illtyd's Church.

Quarry (Glam. 41 NE λ 2), at the roadside east of the village, and 500 yards west of Llanharry Station.

Old Quarry (Glam. 41 NE λ 3), 230 yards south-south-east of St. Illtyd's Church.

All the exposures specified above, except the last-named, exhibit the highly-variable beds of the *Modiola* phase. The last-named exposure shows a crinoidal oolite with abundant brachiopods, which may lie either within, or just below, the *Modiola* phase.

In the same district, the following are the chief exposures of the *Seminula* Oolite:—

At Craig-yr-Eos, on the southern side of Mynydd Ruthin: a level near the top of the *Seminula* Oolite.

Old Quarries lying south and east of Argoed-isaf, a mile and a quarter south-west of Llanharry: horizons rather low in the *Seminula* Oolite.

The Llanharry Limestone Company's Quarry (Glam. 41 NE λ 1), east of Llanharry, and 500 yards south-west of Llanharry Station. This gives an extensive section. The rocks are oolites and oolitic limestones, poorly fossiliferous on the whole. Some bands of calcite-mudstone are developed.

Old Quarry (Glam. 41 NE λ 6), on the west side of the road, 300 yards south-west of the last-named quarry: thickly-bedded, grey, crinoidal oolite which must lie very near the base of S_2. Fossils are abundant. Some bands are crowded with *Productus corrugato-hemisphericus* or *Seminula ficoides*, and both *Cyrtina carbonaria* and *Carcinophyllum vaughani (?)* occur commonly. *Nematophyllum minus* has been found at this locality only.

Between the exposures near Llanharry, just described, and the ground north of Creigiau, a distance of 4 miles, the only good exposure of beds in the Main *Seminula* Zone is that afforded by the Bute Quarries (Glam. 42 NW λ 3), half a mile north-east of Miskin. These quarries lie in the *Seminula* Oolite. They expose thickly-bedded grey oolite, with a small development of

pseudo-concretionary structures, and some bands of chinastone-limestone, the latter containing seams crowded with *Seminula ficoides*.

In the disturbed ground adjacent to the Creigiau Fault, the *Seminula* Oolite is found to be much ironstained and almost wholly vein-dolomitized, as shown a little west of the fault by a railway-cutting a third of a mile north of Creigiau Station, and on the eastern side of the fault by crags on the steep hillside below Coed-y-Creigiau. The highest beds of Creigiau Quarry, much fault-shattered and dolomitized, probably belong to the base of the *Seminula* Oolite.

Half a mile north-east of Creigiau an old quarry (Glam. 36 SE λ 7) lying 100 yards north-north-west of Pen-Llwyn exposes highly fossiliferous beds of grey oolite and oolitic limestone, overlain by dark limestones with beautifully developed pseudo-concretionary structures. This section appears to lie within the *Seminula* Oolite.

The *Modiola* phase of S_2 is evidenced by many small exposures along the outcrop extending from the Creigiau Fault to Pen-y-garn and farther east. The most easterly exposures occur at the roadside 500 to 900 yards east-north-east of Capel-Horeb, Pen-y-garn: they show oolitic and compact nodular limestones, with abundant *Seminula*.

In the Taff valley, Cwarre Glâs (Glam. 36 SE λ 3), on the steep north-eastern slope of Garth Wood (Pl. XIII, fig. 1), is a long-disused, picturesque quarry in the *Seminula* Oolite: vein-dolomitization is very extensive here.

An old quarry in the woods 450 yards south-west of Cwarre Glâs shows dark-grey finely-oolitic limestones overlying coarse oolite. This probably represents the top of the *Seminula* Oolite.

Below the *Seminula* Oolite of Cwarre Glâs lies the monotonous series of crystalline dolomites which form the bulk of the Main Limestone in the Taff valley. On the evidence of fossils found on the opposite side of the gorge (p. 150) the topmost portion of this dolomite series is of S_2 age.

Lower *Dibunophyllum* Zone: D_1.

The beds assigned to this subzone contain a characteristic assemblage of corals with *Dibunophyllum* θ, *Carcinophyllum vaughani*, and *Cyathophyllum murchisoni* as essential members.

The *Dibunophyllum* beds are apparently confined to that part of the district which lies west of the Ely river. They have not been traced farther east than the ground immediately north of Brynsaddler, in the Ely valley, and in all probability their base is overstepped by the Millstone Grit in the drift-covered area north of Brynsaddler.

Around Ruthin, in the extreme west of the district here described, persistent northerly dips over a wide outcrop indicate a thickness of about 600 feet of limestone above the *Seminula* Zone, before the Carboniferous Limestone finally disappears beneath the Keuper on the north. Of this thickness, about 450 feet can be assigned to D_1 on conclusive faunal evidence: higher beds in the Ruthin outcrop may belong either to D_1 or to D_2, but the fossils which have been yielded by the meagre exposures of these beds are of no zonal value.

Lithology.—Chiefly grey crinoidal and shelly limestones, often highly crystalline, and occasionally oolitic. A characteristic feature in this district, as in Gower and elsewhere, is the extensive development of pseudo-brecciated structures [1] in the limestones.

[1] First described by Mr. R. H. Tiddeman, 'The Country around Swansea' Mem. Geol. Surv. 1907, p. 10.

The pseudobreccias, like those of Gower, are highly foraminiferal. The peculiar structure of these rocks, which has been attributed by Mr. E. E. L. Dixon [1] to the patchy and early recrystallization of a calcareous mud, results in a characteristic honeycomb-weathering. Beds of red-stained, rubbly limestone are associated with the pseudobreccias. At a high level in the subzone are developed some dark-grey fine-grained limestones, approximating to calcite-mudstones; they contain *Calcisphæra (?)* and many foraminifera.

Fauna:

Corals and brachiopods:—

Syringopora spp.—λ 4.
Alveolites septosus (Fleming), Edwards & Haime.—λ 4.
Cyathophyllum murchisoni Edwards & Haime.—λ 3, λ 4, λ 5.
Lithostrotion irregulare (Phillips).—λ 3, λ 5.
Lithostrotion martini Edwards & Haime.—λ 3.
Carcinophyllum vaughani Salée.—λ 3, λ 4.
Dibunophyllum θ Vaughan.—λ 3, λ 4, λ 5.
Productus hemisphericus J. de C. Sowerby.—λ 4, λ 5.
Productus cf. *giganteus* (Martin).—λ 3, λ 4.
Papilionaceous *Chonetes*.— 3, λ4, λ5.
Spirifer cf. *striatus* (Martin).—λ 4 (rare).
Martinia glabra (Martin).—λ 4 (rare).
Cyrtina septosa (Phillips).—λ 4.
Seminula ficoides Vaughan.—λ 3, λ 4, λ 5.
Athyris cf. *expansa* Davidson, *non* (Phillips).—λ 4, λ 5.

λ 3, λ 4, and λ 5 are localities near Ruthin, in the 6-inch sheet Glamorgan 41 NW, to be described immediately.

The following are the best exposures of the D_1 beds in the outcrop around Ruthin:—

Quarry (Glam. 41 NW λ 3), immediately north of the Roman Camp, Ruthin. This exposes a level at or very near the base of the *Dibunophyllum* Zone. The rocks are highly-crystalline grey limestones, in several beds of which *Dibunophyllum θ* is extremely abundant.

Old Quarry (Glam. 41 NW λ 4), 100 yards north of Tyle-gwyn, west of Ruthin. This section, lying much higher in the subzone, shows pseudobreccias and rubbly limestones.

Exposures (Glam. 41 NW λ 5), on the northern edge of Coed Garwa, east of Ruthin. These show highly-fossiliferous beds of pseudobreccia, rubbly limestone, and finely-saccharoidal grey limestone. One band has yielded pygidia and a cranidium of *Griffithides* sp.

East of a point about midway between Ruthin and Llanharry, the D_1 beds, in so far as they have not been overstepped by the Millstone Grit, are almost wholly concealed by Keuper and Glacial drift. But a small, disused quarry, at Llechau Farm, half-way between Llanharry and Brynsaddler, has yielded *Dibunophyllum θ* and *Lithostrotion irregulare*; and the spoil-heap of an abandoned iron-mine situated north-west of Brynsaddler, and about 100 yards south-east of Ty-du Reservoir, contains blocks of grey crinoidal limestone which have yielded *Dibunophyllum θ*. These are the most easterly indications of the *Dibunophyllum* Zone.

[1] Gower paper, pp. 507–11.

East of the Taff.

The Main Limestone is better exposed than in the area west of the Taff. But the overstep of the Millstone Grit, which has already progressed below the top of S_2, cuts out the whole of that zone before the Ebbw valley is reached, while dolomitization and the development of *Modiola* phases obliterate so much of the faunal succession that only two zonal horizons (Z_1 and the base of S_2) can be traced.

No trace of the C_1 fauna has been found, and only vestiges of the C_2+S_1 fauna. It has not been possible, therefore, to define a boundary between C_1 and C_2. The line drawn on our map (Pl. XVI) does not, however, represent a conjectured zonal boundary. From Cefn-carnau-fawr, about 2 miles east of the Taff, to Pen-how, 1 mile west of the Rhymney, it is a definite lithological division-line. It marks the base of a band of crystalline dolomites, of C_2+S_1 age, which becomes defined, as we proceed north-eastwards, by the appearance of underlying and overlying argillaceous *Modiola* phases. This dolomite-band must be assigned to C_2+S_1 from its position in the sequence, which can be determined accurately at Thornhill and on Cefn-On (p. 151). But considerations of thickness indicate also that some part of the underlying *Modiola* phase belongs to C_2, and lead to the conclusion that this *Modiola* phase is of C_1–C_2 age. In the central portion of the outcrop between the Taff and the Rhymney, therefore, the line drawn on our map separates an argillaceous *Modiola* phase of C_1–C_2 age from a band of crystalline dolomite belonging to C_2+S_1. West of Cefn-carnau-fawr, and east of Pen-how, it represents merely the conjectured position of the same level. The argillaceous group ceases to be recognizable a little west of Cefn-carnau-fawr, while the dolomite-band appears to die out and give place to argillaceous beds east of Pen-how.

The Main Limestone on the eastern side of the Taff gorge.

Almost the whole thickness of the Main Limestone is exposed in quarries and railway-cuttings on the eastern side of the Taff gorge.[1] The cuttings on the Cardiff Railway, together with Castell-Côch Quarry and Portobello Quarry, afford a section which is practically continuous from the base of the Main Limestone almost up to the top of the *Seminula* Oolite; while the Barry Railway, which has crossed the gorge on the Walnut-Tree viaduct, cuts into the C_2+S_1 beds and provides a duplicate section from this latter horizon upwards (see photograph, Pl. XIII, fig. 1).

The succession may be tabulated as follows:—

		Feet.
S_2	Oolite and oolitic limestone	380
	Dolomites	130
C_2+S_1, C_1, Z	Dolomites	1250
	Total	1760

The Z_1 fauna is poorly represented, and traces of the C_2+S_1 fauna are found. The S_2 fauna is well represented, and the base of S_2

[1] The succession is briefly described in the Newport Memoir, 2nd ed. pp. 20, 24–25.

has been drawn at a level marked by the appearance of *Cyrtina carbonaria*.[1]

The estimates of thickness should be regarded as rough approximations, except in the case of the S_2 dolomites, the thickness of which can be determined with fair accuracy. Allowance has been made for some probable repetition, by thrusts, of beds within the S_2 oolites. Both the dolomites of Z C_1 and the oolitic beds of S_2 are much broken and sheared, doubtless owing to the close proximity of the sections to the great dip-fault which runs along the gorge. The dip varies from about 60°, slightly west of north, in the lower beds, to about 20°, north-westwards, in the upper part of S_2. Calcite-veining on both a large and a small scale is greatly developed throughout, and nests of calcite and dolomite are abundant in the dolomites generally. Although the dolomites are mainly contemporaneous, portions of the sequence, in C_2+S_1 and in S_2, owe their dolomitic character to vein-dolomitization. The problem of the dolomitization is not discussed here, however.

Castell-Côch Quarry (Glam. 37 SW λ 5), a great quarry which extends almost as far north as the Walnut-Tree viaduct, exposes the grey finely-crystalline dolomites which form the lower half of the Main Limestone. These beds cover Z and probably the whole of C_1. As mentioned on p. 131, the section includes the junction of the Main Limestone with the Lower Limestone Shales, and this junction is sharp. The basal beds of the Main Limestone are grey or buff-coloured argillaceous dolomites, with some very thin shale-partings. They include some richly-crinoidal seams, and show a small development of crinoidal chert. Their horizon (Z_1) is indicated by an abundance of *Productus burlingtonensis*, associated with *Schellwienella* cf. *crenistria* and *Syringothyris* cf. *cuspidata*, observed on a shaly bedding-plane.

Beds assignable to C_2+S_1 are exposed (*a*) in the low-level cutting of the Cardiff Railway, under and immediately north of the Walnut-Tree viaduct, and (*b*) in the high-level cutting of the Barry Railway. In the main, these are grey or yellow, fine-grained to medium-grained dolomites, barren of fossils. They include occasional bands of dolomite-mudstone and lenticles of clay, features which foreshadow the strong development of *Modiola*-phase deposits farther east. They have yielded a few fossils. On the Cardiff Railway, *Syringopora* cf. *reticulata (?)* and *Productus corrugato-hemisphericus* have been recorded. On the Barry Railway (Glam. 37 SW λ 6), about 110 yards from the viaduct wall, a band of yellow dolomite contains colonies of *Lithostrotion martini* with the tissue completely dolomitized. This band lies about 35 feet below the base of S_2. Patches of slightly-dolomitized, pale-grey oolite survive in a massive dolomite exposed on the Cardiff Railway 65 yards north of the viaduct. This is the easternmost trace of the normal oolites of C_2+S_1 discovered in our district.

The dolomites which form the lowest part of S_2 are best exposed on the Barry Railway (Glam. 37 SW λ 6). They are grey slightly-crinoidal rocks, fine-grained to medium-grained, and thinly bedded, with occasional clay-partings. At their base, *Cyrtina carbonaria* and *Seminula ficoides* are represented by numerous casts in a band of dark-grey dolomite, red-stained in patches. This band, defining the base of S_2, lies 140 yards from the wall of the Walnut-Tree viaduct, on the eastern side of the cutting. Except in this basal band, fossils other than crinoid-ossicles are rare in these dolomites. *Productus* sp., *Seminula ficoides*, and *Carcinophyllum* sp. have been identified.

[1] Here, as elsewhere east of the Taff, the dolomites with *Cyrtina carbonaria* which form the lowest part of S_2 represent the basal portion of the *Seminula* Oolite as developed farther west.

The passage into the overlying oolites is well exposed in the same cutting. No definite division-line can be drawn, because dolomitization has affected the basal portion of the oolite very extensively, spreading not only in veins along joints, but also in masses which involve the body of the rock.

The Barry Railway also affords a good section of the oolites; but these beds are even better displayed in Portobello Quarry, which lies between the two railways, and in the cuttings on the Cardiff Railway. They exhibit the typical lithology and fauna of the *Seminula* Oolite, although everywhere veined by dolomite and calcite. In the northern portion of each railway-section the beds are much shatter-jointed and traversed by occasional faults, probably thrusts. The following corals and brachiopods have been recorded:—

Syringopora sp.	*Caninia* sp.; rare.
Lithostrotion martini.	*Productus corrugato-hemisphericus*; common.
Lithostrotion (Nematophyllum) minus (lower beds only); rare.	Papilionaceous *Chonetes*; common.
Carcinophyllum sp.	*Seminula ficoides*; abundant.

Northwards, the section of Carboniferous Limestone terminates in the *Seminula* Oolite on both railways. On the Cardiff Railway, limestone extends to the end of the cutting, where the ground falls abruptly to an alluvial terrace. On the Barry Railway, the limestone-section terminates within the cutting, at the point where a bridge crosses, and the rest of the cutting lies in Glacial gravel. Glacial drift probably covers about 100 feet of S_2 beds at the top of the Main Limestone in this locality. The northernmost exposure of limestone is a small outcrop in a lane immediately east of the Barry Railway, 65 yards south of Ty-rhiw.[1] The rock is an oolitic limestone containing comminuted shell.

The Main Limestone east of the Taff gorge.

As explained in the general account of the succession (§ IV, pp. 122–23) and illustrated by the vertical sections (fig. 2, p. 119), the Main Limestone, when traced north-eastwards from the Taff valley, undergoes three important changes, namely (1) the loss of S_2 in consequence of overstep by the Millstone Grit, (2) the attenuation of the surviving zones, and (3) the great development of *Modiola*-phase deposits in C–S_1.

Abundance of exposures enables us to establish the succession of beds in considerable detail at Thornhill, and again in the vicinity of Cefn-On Farm, 1½ miles east-north-east of Thornhill. There is little change between these points. The Cefn-On sequence, which is illustrated by a horizontal section (fig. 4, p. 120) and by a vertical section in fig. 2 (p. 119), may be tabulated to provide a basis for the description of the Main Limestone between the Taff and the Ebbw.

The Main Limestone of Cefn-On.

			Feet.
(iii)	S_2 (basal beds of).	Dolomites with a band of oolite	70
(ii)	C_2+S_1.	*Modiola* phase (S_1)	50
		Crystalline dolomite and dolomitic limestone (C_2 S_1)	100
	C_1 (part of)	*Modiola* phase (C_1–C_2)	250
(i)	C_1 (part of) / Z	Dolomites, with some chert near the base	450
		Total	920

[1] There is no exposure at the point, 25 yards south-west of Ty-rhiw, marked by a dip-arrow on the 6-inch Geological Survey map (Glamorgan, 37 SW).

In this sequence the divisions (i), (ii), and (iii), and the subdivisions of (ii), are well-defined lithologically. The zonal correlation of the S_2 beds is placed beyond question by the occurrence of *Cyrtina carbonaria* and other fossils, but that of the underlying beds is inferred from considerations of thickness, in comparison with the faunal succession established west of the Taff.

These three divisions of the Cefn-On sequence may be conveniently adopted for the remaining description of the Main Limestone.

(i) The crystalline dolomites of Z–C_1.

In the Taff valley, these dolomites probably cover the whole of Z and C_1 (p. 150). Eastwards, the upper beds pass laterally into *Modiola*-phase deposits. As a result of this circumstance, combined with actual thinning of the strata, the thickness diminishes from about 800 feet in the Taff valley to 400 feet in the Ebbw valley.

In general, the rocks are grey finely-crystalline dolomites. Nests of calcite and dolomite are sometimes abundant. Chert is usually developed at or near the base. Oolite, completely dolomitized, is developed in considerable thickness, less than 100 feet above the base, in Cefn-garw Quarry and in an adjacent disused quarry, and has been observed at the same horizon in the scarp-face of Cefn-On.[1] Fossils, other than crinoid-débris, which is generally distributed and sometimes abundant, are usually rare. At two localities to be described, however, they occur abundantly at and near the base; and at various levels and localities *Schellwienella* cf. *crenistria* and *Spirifer clathratus* have been observed. Excellent exposures are afforded by Cefn-garw Quarry, north of Tongwynlais; Gelli Quarry, north of Rhubina; quarries at Thornhill; crags and cuttings on Cefn-On; Machen Quarry; and Dan-y-Graig Quarry, Risca.

Cefn-garw Quarry (Glam. 37 SW λ 2), situated 750 yards east-north-east of Castell Côch, gives an admirable section of about 60 feet of beds lying very near the base of the Main Limestone. The lower beds of the quarry are blue-black, buff-weathering, crinoidal dolomites of very fine grain. The middle beds are pale to dark-grey richly-crinoidal dolomites. These latter are characterized by a highly-irregular development of black argillaceous streaks, by extensive silicification resulting in patches of crinoidal chert and occasional nodules of chalcedony, and by an irregular patchy iron-staining. They resemble closely the crinoidal limestones which form the base of the Main Limestone west of the Taff (p. 135). Their correlation with Z_1 (Horizon β) is determined by the following fossils found in them:—

Zaphrentis delanouei (?).
Chonetes cf. *hardrensis*; common.
Leptæna analoga; common.
Schellwienella cf. *crenistria*; common.
Camarotœchia mitcheldeanensis common.
Spirifer clathratus.
Syringothyris cf. *cuspidata*.
Spiriferina octoplicata, mutation β.

[1] Specimen E 7423 in the collection of the Geological Survey, obtained from the lower part of the Main Limestone east of the Ebbw river at Risca, is a dolomitized oolite of identical character. See Newport Memoir, 2nd ed. Plate, fig. 5 (microphotograph).

The upper beds of the quarry are grey crinoidal dolomites, highly oolitic in some beds, and containing *Schellwienella* cf. *crenistria* and *Spirifer clathratus*.

In the Rhymney valley, a cutting on the Brecon & Merthyr Railway (Mon. 27 SE λ 1), immediately below Machen Quarry, exposes the base of the Main Limestone. The section shows 8 or 10 feet of thinly-bedded, dolomitic limestones, with some highly argillaceous bands and an abundant development of crinoidal chert, underlying grey dolomites without chert. The change from the argillaceous, cherty beds to the normal grey dolomite is sharp. The lowest bed exposed is a band of dark-grey crinoidal limestone, slightly cherty but non-dolomitic, and containing *Chonetes* cf. *hardrensis* and *Chonetes crassistria* Vaughan (*non* M'Coy) in profusion, together with *Spirifer clathratus* and *Schellwienella* cf. *crenistria*.

The grey dolomites of this railway-cutting and Machen Quarry show none of the special features of the beds in Cefn-garw Quarry, described above. In Dan-y-Graig Quarry, Risca, the base of the Main Limestone, again exposed, shows fine-grained dolomites alternating with hard dolomitic shales, and the beds contain only some scanty crinoid-débris. There is evidently much variation in the character of the lowest beds of the Main Limestone between the Taff and the Ebbw.

(ii) The *Modiola* phases, etc., of C_1–S_1.

The sequence clearly defined on Cefn-On, comprising two *Modiola* phases with an intervening band of crystalline dolomites, can be traced for about 2 miles along the outcrop in each direction, west-south-westwards to the neighbourhood of Cefn-carnau-fawr, and east-north-eastwards to the vicinity of Pen-how. Along this portion of the outcrop a colour-boundary on our map (Pl. XVI) represents the base of the dolomite-band, as explained on p. 149. Farther west, the *Modiola* phases cease to be traceable. Farther east, the dolomite-band has not been recognized; and, by the time the Rhymney valley is reached, the whole division has probably assumed the essential character of a *Modiola* phase, which it presents in the Ebbw valley.

On the eastern side of the Rhymney valley, in the ravine below Ffwrwm, the Millstone Grit oversteps the base of S_2, and comes to rest directly upon the C–S_1 beds. This sharp transgression, which is associated with the development of a band of quartz-conglomerate at the base of the Millstone Grit, continues as far as the crest of the ridge between the Rhymney and the Ebbw, and so cuts out a considerable thickness of C–S_1 beds. On the descent to the Ebbw River, however, the quartz-conglomerate dies out, the base of the Millstone Grit retrogresses, and the upper beds of C–S_1 emerge almost completely.

The lower *Modiola* phase (C_1–C_2) is by far the thickest group, and attains a thickness of some 250 feet on Cefn-On. It is composed largely of dolomite-mudstones, very varied in colour, with thin partings and lenticles of shale and clay, and a considerable intercalation of very fine-grained, crystalline dolomites. In the middle and upper portions, compact grey limestones, mostly calcite-mudstones with conchoidal fracture, may be developed in large or small amount. No fossils have been observed.

On the dip-slope of Cefn-On, about 200 yards west of the line of the Caerphilly Tunnel, the southern quarry in some old workings (Glam. 37 NW λ 1) affords a good exposure of the uppermost beds. These are dolomite-mudstones, with some dolomitic shale in the lower part and a regular intercalation of finely-crystalline dolomites in the upper part. Some bands of nodular dolomite-mudstone in the lower beds contain calcitic patches. The overlying crystalline dolomite comes on in the northern part of these workings (see below).

In the Cefn-On Farm traverse (horizontal section, fig. 4, p. 120), the lower beds of the group are exposed in a cutting on the cart-road, 120 yards north-north-west of the farm. These are dolomite-mudstones with a little purple-and-green shale and a few bands of crystalline dolomite. Another cutting, 70 to 80 yards farther north on the cart-road, exposes dark-grey calcite-mudstones, with platy bedding and shale-partings, which lie about the middle of the group.

Many small exposures occur in the neighbourhood of Maenllwyd, east of Rudry. A well-developed dry valley marks the outcrop of the group north and north-east of the Maenllwyd Inn. An old quarry on the northern side of this valley, situated 130 yards north-north-west of Tir-Sion-Philip-Morgan, exposes beds near the top of the group, compact limestones and fine-grained dolomites with some shale and marl.

The band of crystalline dolomite and dolomitic limestone (C_2–S_1), which can be traced from Cefn-carnau-fawr to Pen-how, gives rise to a well-marked feature along much of this distance. Its thickness amounts to 120 feet or more at Thornhill, and to about 100 feet on Cefn-On. It includes rocks which vary much, as regards both size of grain and degree of dolomitization. Fairly-pure dolomites predominate, but a considerable amount of partly-dolomitized limestone is also found. Dolomitized oolite occurs in small amount on Cefn-On. Fossils, other than crinoid-ossicles, have been found at one locality only, on Cefn-On.

On Cefn-On, in the old workings (Glam. 37 NW λ 1) which lie 200 yards west of the line of the Caerphilly Tunnel, the northern quarry, much overgrown, exposes the lower beds of this group. The rocks are grey saccharoidal dolomites, coarse-grained for the most part, but including some fine-grained bands. On the cart-track which skirts this quarry, some bands of fine-grained dolomite have yielded *Bellerophon*, *Schellwienella* cf. *crenistria*, *Seminula* sp., and crinoid-ossicles, all preserved as casts or moulds.

The upper *Modiola* phase (S_1) is a very variable group averaging roughly 50 feet in thickness. The rocks are mainly calcite-mudstones and dolomite-mudstones, or closely-similar compact limestones and dolomites[1]; but they also comprise some medium-grained oolites and some persistent beds of crystalline dolomite. In all these, very fine quartz-sand, in small or moderate amount, is ubiquitous. Thin shale-bands are frequent.

Unmistakable vein-dolomitization has everywhere affected the limestones to some extent, and in places it has produced an extensive conversion of limestone, amorphous-looking in its original state, into coarsely-crystalline dolomite. This is well seen in stream-sections on both sides of the Rhymney valley: on the

[1] Types covered by Mr. E. E. L. Dixon's description of 'Calcite-mudstones and similar rock-types,' Gower paper, pp. 516–17.

western side, in the woods west of Rhŷd-y-Gwern, and on the eastern side, in the ravine west-south-west of Ffwrwm.

In the limestones, ostracods and *Calcisphæra (?)* are sometimes abundant, crinoid-débris and foraminifera occur more sparingly, and serpulids occur rarely. The fauna is, therefore, decidedly that of a *Modiola* phase.[1]

This *Modiola* phase is immediately overlain by the dolomites with *Cyrtina carbonaria* which represent the base of S_2. Its zonal horizon (S_1) is, therefore, quite definite. As far east as Pen-how its base is defined by the underlying band of crystalline dolomites; but farther east, where that band dies out, it forms merely the uppermost part of the very thick *Modiola* phase of C_1–S_1 age in the Rhymney and Ebbw valleys.

The best sections are afforded by (1) an old quarry (Glam. 37 NE λ 1) situated about midway between Pen-y-waun and Pen-how, north-east of Rudry, and (2) the stream-bed and banks in the ravine (Mon. 27 SE λ 2) immediately west-south-west of Ffwrwm, on the eastern side of the Rhymney valley. At the first-named locality, dolomite-mudstones and crystalline dolomites predominate over calcite-mudstones. In the Ffwrwm ravine, dolomites are subordinate to a variety of calcite-mudstones and other fine-grained limestones, while a thick band of dark-grey oolite forms a conspicuous feature.

In the Ebbw valley, the C_1–S_1 *Modiola* phase, apparently unbroken, attains a thickness of about 275 feet. It is succeeded directly by the shales of the Millstone Grit,[2] but the junction is not now exposed. The strata, poorly exposed in the cutting on the railway east of Waun Fawr Brickworks, are chiefly dolomite-mudstones, with much very fine-grained crystalline dolomite and some coarsely-crystalline dolomite. Very near the Millstone-Grit boundary, near Buck Farm on the hillside south of the railway, some small outcrops of smooth-textured oolitic limestone, containing ostracods, suggest the S_1 horizon of the ravine below Ffwrwm in the Rhymney valley.

(iii) The S_2 beds.

It has been seen (p. 149) that the S_2 beds on the eastern side of the Taff gorge comprise some 130 feet of dolomites succeeded by nearly 400 feet of oolites and oolitic limestones. At Pen-y-bryn, a mile away to the north-east, dolomites about 150 feet thick alone represent S_2. This rapid apparent thinning can only be explained by overstep of the Millstone Grit. East-north-eastwards from Pen-y-bryn to the Rhymney valley, the dolomites of S_2 diminish but gradually in thickness, for they amount to 100 feet at Thornhill, 60 feet or more on the dip-slope of Cefn-On, and probably 50 feet in the Rhymney valley. On the eastern side of that valley, however, they are cut out by a sharp transgression of the quartz-conglomerate at the base of the Millstone Grit.

[1] See E. E. L. Dixon, Gower paper, pp. 518–19.
[2] Newport Memoir, 2nd ed. p. 21.

These basal beds of S_2 are grey crystalline dolomites, fine-grained or medium-grained. Being much more resistant to denuding agents than either the underlying *Modiola* phase or the overlying shales of the Millstone Grit, they give rise to a conspicuous feature along much of their outcrop. They can readily be mapped, and at many points they have yielded the characteristic brachiopod *Cyrtina carbonaria* and other fossils.

In Fforest Fawr and the woods adjacent to it on the north, are a few exposures of the S_2 dolomites and many of the overlying oolites. The latter beds are extensively vein-dolomitized in mass, and often rendered highly ferruginous by the development of hæmatite. An old quarry beside the road, immediately south of Pen-y-bryn Cottage, gives a small exposure of ferruginous crinoidal dolomites containing *Cyrtina carbonaria*.

The following tabular list of fossils records most of the fossiliferous exposures of the S_2 beds in their outcrop from Pen-y-bryn to the Rhymney valley.

Genera and species.	Locality.						
	1.	2.	3.	4.	5.	6.	7.
Syringopora sp.	...	×	...	...	...	...	...
Lithostrotion martini Edwards & Haime.	×	×	...	...	×	...	...
Carcinophyllum sp.	×	×	...	...	×	...	...
Productus corrugato-hemisphericus Vaughan	...	×	...	...	...	...	×
Cyrtina carbonaria M'Coy	×	×	×	×	×	×	...
Seminula ficoides Vaughan	×	×	×	×	×	×	×

1. Old Quarry (Glam. 37 SW λ 7), 350 yards north-west of Cefn-carnau-fawr.
2. Old Quarries (Glam. 37 SW λ 8), immediately south-east of Ty'n-y-ton, north of Thornhill.
3. Old Quarries (Glam. 37 SW λ 9), immediately west of Cefn-carnau-uchaf, north-north-east of Thornhill.
4. Bed of lane (Glam. 37 NW λ 2), on the northern side of Cefn-On, a quarter of a mile west of the Caerphilly railway-tunnel.
5. Old Quarry (Glam. 37 NE λ 3), in woods north of Cefn-On Farm, 200 yards east-north-east of Ty'n-y-parc.
6. Footpath (Glam. 37 NE λ 2), 100 to 150 yards north-east of Pen-y-waun, north-east of Rudry.
7. Stream-bed (Mon. 27 SE λ 2), about 100 yards west of Ffwrwm, eastern side of the Rhymney valley.

In all cases except one, the fossiliferous beds are grey dolomites. The exception is afforded by the old quarry (Glam. 37 NE λ 3) near Ty'n-y-parc, where a band of coarse-grained white oolite yields the fossils. This oolite is probably succeeded immediately by the Millstone Grit.

Below Ffwrwm in the Rhymney valley, where the S_2 beds are last seen, they crop out in the stream-bed and in the very steep northern side of the ravine, and they are seen to overlie the *Modiola* phase of S_1. About 30 yards upstream from their last outcrop, a band of quartz-grit crosses the stream-bed; and the quartz-conglomerate, of which this grit probably forms the basal bed, undoubtedly cuts out the S_2 dolomites in this locality.

VI. Summary and Conclusions.

Summarizing the results of our investigation of the changes which affect the Carboniferous Limestone Series when traced north-eastwards along its outcrop between Bridgend and Risca, we find that:—

(1) The diminution in thickness is due only in part to actual attenuation of the strata, a factor of greater importance being the overstep of the Millstone Grit across successively lower horizons in the Carboniferous Limestone.

(*a*) Unconformable overstep by the Millstone Grit cuts out the *Dibunophyllum* beds and the Main *Seminula* Zone (S_2), the collective thickness of which in the extreme west of the outcrop amounts to some 1200 feet.

(*b*) Actual attenuation diminishes the collective thickness of the surviving zones—K (Lower Limestone Shales), and Z to S_1 (Main Limestone)—by some 700 feet, from about 1500 feet in the west to 800 feet in the east.

(2) The Lower Limestone Shales maintain their lithological and faunal facies substantially unaltered.

(3) The zones of the Main Limestone which persist throughout (Z to S_1, inclusive) undergo great changes in lithological and faunal character.

(*a*) In the Taff valley, the sequence of undolomitized limestones with subordinate dolomites which obtains in the west has given place to an almost unbroken succession of dolomites. This is due to a progressive increase in the vertical extent of contemporaneous dolomitization. The faunas, although largely obliterated, maintain a standard facies.

(*b*) East of the Taff valley, the lower beds (Z C) maintain the character of crystalline dolomites with remnants of the standard fauna. The upper part of the sequence (C–S_1), however, becomes a *Modiola* phase of great thickness, composed essentially of dolomite-mudstones with subordinate calcitic beds.

Our investigations confirm, therefore, the opinion previously expressed by Mr. E. E. L. Dixon[1] that unconformable overstep by the Millstone Grit takes place in this part of the coalfield margin. The discordance of stratification between the Carboniferous Limestone and the Millstone Grit is probably so slight that it would be inappreciable in sections of the junction of the two formations. None the less, the indisputable overstep of the Millstone Grit across a large part of the Carboniferous Limestone Series admits only of the conclusion that the junction is a true plane of unconformity, determined by a period of uplift and denudation during which the beds of the Carboniferous Limestone were shaved off obliquely from the north-east or north. Outside the district here described. several facts suggest that the area of maximum uplift at the time of this earth-movement lay to the north-east, rather than to the north. The attenuation of the Carboniferous Limestone Series continues northwards along the eastern margin of the coalfield, as far as a point near the north-eastern corner of the basin: west of that point, however, the Series thickens rather

[1] Newport Memoir, 2nd ed. p. 20.

rapidly along the 'north crop' of the coalfield.[1] Further, 'Millstone Grit' overlies Carboniferous Limestone unconformably in the Chepstow[2] district, east of the area here described; and Coal Measures succeed the Lower Carboniferous strata with pronounced unconformity in the Forest-of-Dean Coalfield,[3] lying to the north-east. It is very probable that the unconformity now shown to exist on the eastern fringe of the South Wales coal-basin was due to the earth-movement which produced a great break in the Carboniferous succession of the Forest of Dean.

No detailed comparison of the variable succession in the district that has been described in this paper with the Avonian of other areas need be made, but attention may be directed to a few points of interest.

The sequence in the westernmost part of our district, although probably lacking the highest portion of the Avonian, parallels the succession in Gower very closely in other respects.[4] But the remarkable dolomitic sequence in the extreme east of the district here dealt with cannot be matched elsewhere in the South-Western Province: its nearest analogue, to be found in the Forest-of-Dean succession,[5] presents considerable differences.

The interval of Avonian time, K to S_1 inclusive, is represented by deposits which survived the inter-Carboniferous denudation everywhere in the district here described.

K. The slight variation of the deposits of this zone throughout the district accords with the general constancy of facies shown by the K beds throughout the South-Western Province. But the attenuation of the beds in a north-easterly direction indicates that subsidence was more rapid in the south-west than in the north-east.

Z to S_1. The changes of facies and the attenuation of the strata from south-west to north-east indicate (1) that the area of deposit shallowed, as a rule, in a northerly or north-easterly direction, and (2) that subsidence was more rapid in the south-west than in the north-east. The form of the outcrop—a single band trending north-north-eastwards—precludes any discrimination, on local evidence, between the significance of northerly or north-easterly directions in this connexion.

In the interval represented by Z, γC_1, and the *Laminosa* Dolomite the north-eastward shallowing was probably slight, the change of facies amounting to no more than an increase of dolomitization.

In the interval represented by the *Caninia* Oolite and C_2+S_1, however, standard conditions prevailed almost or quite[6] continuously

[1] 'The Country around Abergavenny' Mem. Geol. Surv. 1900, p. 19.

[2] At Ifton (Monmouthshire): E. E. L. Dixon, Geol. Mag. dec. 5, vol. vi (1909) p. 515.

[3] T. F. Sibly, Geol. Mag. dec. 5, vol. ix (1912) pp. 417, 420–21.

[4] E. E. L. Dixon & A. Vaughan, Gower paper. See especially p. 505 and pp. 532–37; and compare table (p. 505) with our table on p. 118.

[5] T. F. Sibly, Geol. Mag. dec. 5, vol. ix (1912) pp. 418–20.

[6] The thin *Modiola* phase developed at the base of C_2 at Miskin has not been detected farther west.

in the south-west of the district here described, while lagoon conditions prevailed without sensible interruption in the north-east.

The thick, dolomitic *Modiola* phase of C_1 S_1 which is developed in the easternmost part of the district agrees, in all its essential features, with the *Modiola* phase of C_2 S_1 which succeeds the *Caninia* Oolite in the Avon, Sodbury, and Tytherington sections of the Bristol area[1] to the south-east and east. In the district here described, however, the phase, commencing in C_1, probably covers the period of the *Caninia* Oolite.

EXPLANATION OF PLATES XII-XVI.

PLATE XII.

Fig. 1. Craig Llanishen, Cefn-On, and the intervening strike-valley: view looking westwards. The features of the middle distance, etc., reading from left to right, that is, from south to north, are as follows:—(*a*) the wooded crest and dip-slope of Craig Llanishen—the quartz-conglomerate and sandstones of the Upper Old Red Sandstone; (*b*) a grassy belt—the highest beds of the Old Red Sandstone and the limestones and shales (1) of the Lower Limestone Shales; (*c*) a wooded ridge—the limestones (2) of the Lower Limestone Shales; (*d*) a grassy belt—the shales (3) of the Lower Limestone Shales; and (*e*) the wooded scarp and crest of the western end of Cefn-On—the Main Limestone. See map (Pl. XVI).—T. F. Sibly, photo.

2. The scarp-face of Cefn-On at the head of Cwm Draethen: view looking eastwards. The features of the middle distance and foreground, reading from left to right, that is, from north to south, are as follows:—(*a*) the steep, wooded scarp of the Main Limestone; (*b*) a grassy flat, made by the shales (3) of the Lower Limestone Shales; (*c*) a low, wooded escarpment, made by limestones in the Lower Limestone Shales; (*d*) the ravine of the Draethen brook, cut in the topmost beds of the Old Red Sandstone; and (*e*) the dip-slope of Craig Lysfaen—Upper Old Red Sandstone. The features (*a*), (*b*), and (*c*) are displaced in this locality by a dip-fault, the track of which enters the picture at the lower right-hand corner and runs up a ravine in the scarp-face of the Main Limestone. In the distance, the Main Limestone escarpment and the high ridge of Craig Ruperra (Old Red Sandstone) appear faintly. See map (Pl. XVI), and section (fig. 4, p. 120).—T. F. Sibly, photo.

3. Machen Quarry, etc.: view looking north-eastwards across the Rhymney valley. The crystalline dolomites forming the lower part of the Main Limestone, in which the quarry is opened, determine a bold wooded ridge. The scarp-face of this ridge falls southwards to (1) a grassy flat, succeeded by (2) a low, wooded ridge, the two features so often caused by the shales and limestones respectively, of the Lower Limestone Shales (compare figs. 1 & 2). The dip-slope of the ridge falls northwards to a cultivated tract which is made by the C_1–S_1 *Modiola* phase of the Main Limestone. The Pennant-Grit scarp of Mynydd Machen enters the left-hand side of the picture. See map (Pl. XVI).—T. F. Sibly, photo.

[1] A. Vaughan, Q. J. G. S. vol. lxi (1905) pp. 193-95 (Avon), pp. 207–209 (Sodbury), pp. 221–22 (Tytherington).

PLATE XIII.

Fig. 1. The gorge of the Taff below Taff's Well: view looking south-eastwards from the eastern end of Garth Hill. The gorge separates the Carboniferous-Limestone ridge of Fforest Fawr on the east from that of Garth Wood on the west (map, Pl. XVI). The wooded dip-slopes of these two ridges appear in the picture. Beyond Fforest Fawr is seen the ridge of Greenmeadow Wood, determined by a quartz-conglomerate at the base of the Upper Series of the Old Red Sandstone. In the foreground, the Taff valley widens in the strata of the Millstone Grit and the Lower Coal Series, and receives a tributary strike-valley, cut in these strata, from the west. In the distance, the limestone-gorge opens out into the lowlands of Old Red Sandstone which extend southwards to Cardiff. Cwarre Glâs lies in the *Seminula* Oolite (p. 147). The quarries and cuttings on the eastern side of the gorge expose almost the whole of the Carboniferous Limestone Series (pp. 128, 130, 131, & 149–51).—F. Dixey, photo.

2. The escarpment of the Main Limestone, Garth Wood: view looking westwards, across the southern end of the Taff gorge, from the hill above Tongwynlais (map, Pl. XVI). Ty-nant Quarry (pp. 136 & 138) is seen at the foot of the escarpment. The Lower Limestone Shales lie buried under drift at the foot of the escarpment.—F. Dixey, photo.

PLATE XIV.

General view of a quarry in C_2–S_1 beds, a quarter of a mile north of Miskin. This quarry (Glam. 42 NW λ 2) illustrates the sequence of the three groups, 10, 11, & 12, recognized in the standard limestones of C_2 and S_1 near Miskin. (See p. 144.) T. F. Sibly, photo.

PLATE XV.

Geological map illustrating the Carboniferous Limestone Series between the Ewenny valley and the Taff valley, on the scale of 2 inches to the mile, or 1 : 31,680.

PLATE XVI.

Geological map illustrating the Carboniferous Limestone Series between the Taff valley and the Ebbw valley, on the scale of 2 inches to the mile, or 1 : 31,680.

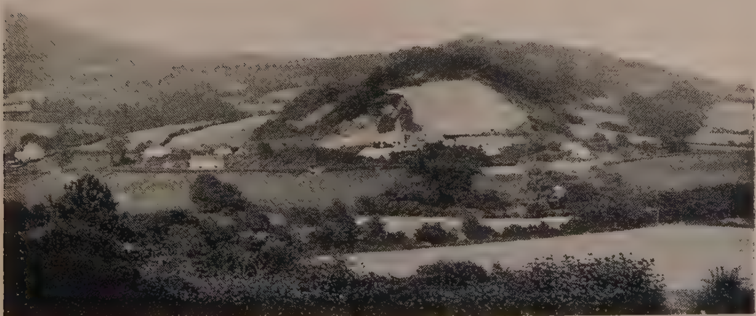
DISCUSSION.

Dr. A. STRAHAN expressed the pleasure with which he saw the details being filled into the outlines which he and his colleagues had drawn many years ago. Part of the outcrop described by the Authors presented exceptional difficulties, for the lithological types were abnormal and fossils were scarce. It would be interesting to see how zones had been mapped under such conditions. It had been known from the first that the limestone series became greatly diminished in thickness from south to north or north-east; and it had long been a matter of discussion how far this was due to an originally meagre development, and how far to overlap by the Millstone Grit. There are, in places, indications of erosion of the limestone-surface below the basal conglomerate of the Millstone

Fig. 1.—*Craig Llanishen, Cefn-On, and the intervening strike-valley: looking westwards.*

Fig. 2.—*The scarp-face of Cefn-On at the head of Cwm Draethen: looking eastwards.*

Fig. 3.—*Machen Quarry, etc., looking north-eastwards across the Rhymney Valley.*



T. F. Sibly, photo.

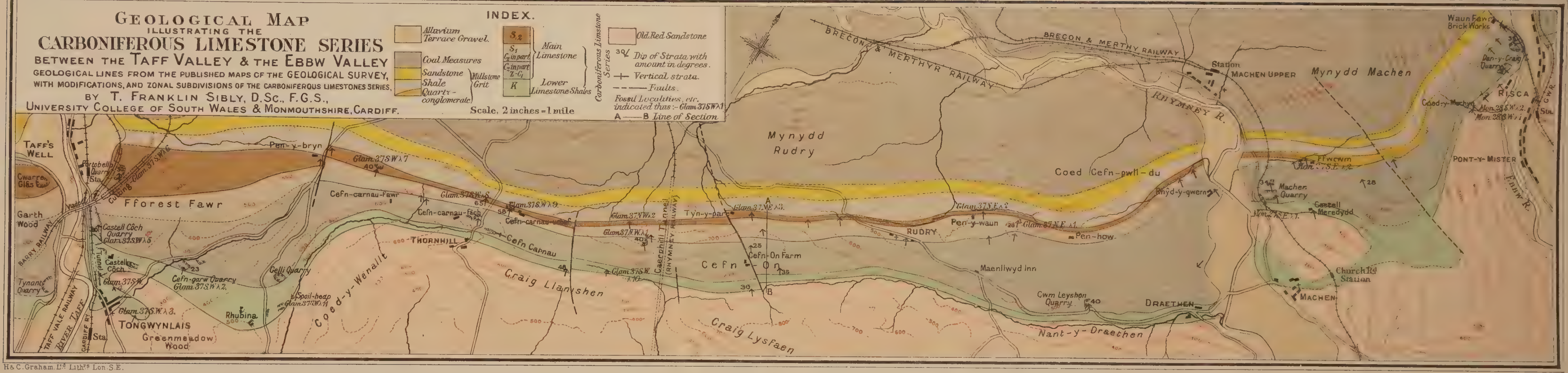
Fig. 1.—*Gorge of the Taff, looking south-eastwards from Garth Hill.*

Fig. 2.—*Escarpment of the Main Limestone, Garth Wood; looking westwards.*

F. Dixey, photo.

General view of Quarry in C_2 S_1 beds, north of Miskin.

T. F. Sibly, photo.



H. & C. Graham Ltd Lithrs Lon. S.E.

Grit, as in the example figured in the Abergavenny Memoir; and, indeed, it was difficult to see how such an area could be invaded by currents strong enough to distribute coarse gravel without some washing-up of the sea-bottom. The matter was complicated by the piping of the limestone, which had taken place on so great a scale as to eventuate in wholesale subsidence of the Millstone Grit and to cause difficulty in mapping its base. He was not satisfied that there was evidence of an unconformity of a pronounced order, such as would involve the supposition of upheaval and prolonged denudation.

All the Carboniferous subdivisions shared in the attenuation, clearly indicating the existence of Carboniferous land at no great distance to the north. The shore-line appeared to have run in a direction generally parallel to the existing margin of the Coalfield. Part of the margin of the Carboniferous Limestone could be recognized in Pembrokeshire, and eastwards near the Welsh Border. The different aspects under which the limestone presents itself at various distances from the shore-line afford an unrivalled opportunity of studying the types developed under littoral conditions, such as dolomites, oolites, pisolites, interbedded conglomerates and others. He looked forward to the prosecution of researches on which so promising a commencement had been made.

Mr. E. E. L. DIXON said that he would refer to two points only. The more important was the overstep of the Millstone Grit across successively lower horizons of the Carboniferous Limestone. This overstep continues along the outcrop that bounds the eastern end of the coalfield, north-east of the area described in the paper. For some miles, however: that is, to beyond Pontypool, it results in little further thinning of the Lower Avonian dolomites; but, from Cwm Afon north-eastwards, it rapidly increases and cuts out almost, if not quite, the whole of the remaining dolomites. Nevertheless the underlying Lower Limestone Shales maintain their thickness unchanged, and present the same rock-types and the same fauna, indicative of the *Cleistopora* Zone, as elsewhere along the outcrop. There can be no doubt that they do not represent the Main Limestone + Lower Limestone Shales of other localities.

This is the extreme amount of the overstep. The outcrop hereabouts swings westwards, and, in that direction, successively-higher subzones of the Main Limestone emerge from beneath the Millstone Grit—so rapidly that in less than 6 miles appear several hundred feet of limestone, in which all the zones, up to the Upper *Seminula* Subzone, S_2, are recognizable.

In this area, also, important confirmatory evidence of the unconformable nature of the Main Limestone Millstone Grit junction has been obtained, of which details will be published later. Although no discordance of dip is to be observed in actual exposures of the junction (which fortunately are to be seen at several places in this area), the latter is sharp and irregular, and in the largest exposure, in the Llammarch dingle near Bryn-mawr, is sufficiently transgressive to cut out 6 feet of limestone in a distance of 35 yards.

The Carboniferous Limestone also, immediately below the junction, is penetrated to a distance of several feet below its upper surface, by pipes and veins of hard grit, pebbly in places, continuous with the overlying, evenly-dipping beds of grit but firmly welded to the enclosing limestone and, on some unweathered surfaces, difficult to distinguish from it at first sight. It is evident that the limestone has been eroded subaërially, and the cavities filled with Millstone Grit. But the even lie of the beds of grit above, the consolidated state (due to siliceous cementation) of the grit-infilling, and the close union of limestone and infilling make it equally evident that the grit, both that infilling the limestone and the bedded grit, has been deposited from the first in the position in which it is now found. That is, the subaërial erosion of the limestone preceded the deposition of the grit. The junction is, therefore, truly unconformable.

The other point mentioned by the speaker was the possibility that knoll-reefs would be found in the Barry area, where, he understood from the Authors, highly-fossiliferous well-bedded limestones attained a great development. For, in a similarly-placed outcrop in Pembrokeshire, small knoll-reefs had been discovered at about the junction of the Lower with the Upper Avonian, the adjacent beds—in fact, the greater part of the Main Limestone—being highly-fossiliferous well-bedded limestones with the fauna distinctive of Zaphrentid phases. Similar phasal deposits appear to be the invariable concomitants of knoll-reefs.

Dr. T. T. Groom said that the Fellows of the Society would see with gratification that the valuable zonal work initiated in the British Carboniferous Limestone by the late Dr. Vaughan was being continued by the Authors. As to their application of the results to the structure of the Forest-of-Dean Coalfield, the speaker, accepting Mr. Kidston's view that the Middle and Lower Coal Measures were absent from this area (a view confirmed by Dr. Arber), had, like the latter, inferred the existence of an unconformity beneath the Coal Measures of the basin. But, when Prof. Sibly later maintained that this was accompanied by extensive overstep within the area, the speaker was unable to agree with him. He asked for evidence in support of the statement that such overstep occurred in the northern part of the basin, and said that, with reference to the south-eastern side, much of which he had mapped on a large scale, he had stated that the supposed overstep of the Coal Measures on to the Old Red Sandstone was due to faulting. He was quite unable to accept Prof. Sibly's interpretation of the section in the Blackpool Valley, where the Carboniferous Limestone dipping at about 70° was supposed to be directly overlain by gently-inclined Coal Measures. The theory of overstep in this district was beset with difficulties, one of which was that, at the time of the deposition of the Coal Measures, the Limestone and associated beds must have shown over the area of overstep a dip nearly equal to that seen at the present time; while the corresponding beds beyond the area were still undisturbed: also that the limestone of the patch underwent

little further tilting; while at a later date that along the north-east side of the basin received a tilt agreeing in amount with the first. Thus the same continuous limestone-band between Mitcheldean and the Blackpool Valley, dipping almost uniformly at from 60° to 70°, must be supposed to have been tilted to the same extent at two different periods: one part before, and another after, the deposition of the Coal Measures. The speaker maintained that the field evidence, part of which was indicated, was decisively in favour of the view that dip-faults and strike-faults together had produced the appearances attributed to overstep, and thought that the unconformity at the base of the Coal Measures was probably so gentle that the dip of these, as seen in single exposures, might not be visibly different from that of the underlying stratum. He demurred, therefore, to the term 'flagrant unconformity' employed in the abstract of the paper.

Mr. F. Dixey, in referring to the very irregular surface of the Carboniferous Limestone upon which the Millstone Grit rests near Abergavenny, and to pipes and caverns of Millstone Grit in the Carboniferous Limestone, mentioned that all the above features, described by Dr. Strahan and Mr. Dixon as occurring on the eastern margin of the South Wales Coalfield, are reproduced in detail near Haverfordwest, on the southern margin of the Pembrokeshire Coalfield, where the Millstone Grit rests unconformably upon the *Dibunophyllum* beds of the Carboniferous Limestone.

Prof. E. J. Garwood congratulated the Authors on the completion of an important piece of work showing the value of detailed zoning in the Lower Carboniferous rocks. He commented on the numerous facts of interest which the paper contained. He would have liked to ask for further information about some of the points brought forward; but, owing to the lateness of the hour, he would confine his observations to the question of the two periods of dolomitization described by the Authors. In Westmorland the dolomitization of the Lower Limestones in the Shap district could be proved to have taken place contemporaneously with the deposition of the beds; but the rocks also contained cavities lined with crystals of dolomite, which must have been deposited subsequently to the consolidation of the deposit. In this case the material for the crystals must have been leached out of the upper portion of the dolomite and redeposited from solution: the speaker would like to ask the Authors whether the secondary dolomitization described by them might not be due to a similar process, or whether they had evidence that the material which produced the second dolomitization had been introduced at a subsequent geological period.

Prof. T. F. Sibly thanked Dr. Strahan, Mr. Dixon, and Prof. Garwood for their appreciative remarks. Mr. Dixon's interesting description of the phenomena on the eastern and northern margins of the coalfield afforded a gratifying confirmation of the Authors' conclusions. As to the problem of dolomitization discussed by Prof. Garwood, the vein-dolomites were developed on too

large a scale to be attributed mainly to material leached out of the contemporaneous dolomites, although some such redistribution of dolomite had doubtless taken place.

He had not anticipated that this would be made the occasion of an attack by Dr. Groom upon the interpretation of the succession in the Forest-of-Dean Coalfield which he (the speaker) had published more than four years ago. He adhered in every particular to the conclusions then published. The unconformity was quite unmistakable. It was evidenced by continuous transgression of the Coal Measures across the Lower Carboniferous strata (Carboniferous Limestone and Drybrook Sandstone) on the northern and eastern borders of the coalfield; by a great difference in the inclination of the two series of strata all along the eastern margin from Mitcheldean to Howbeach; and incidentally by marked angular discordance at the junction exposed in an old quarry near Howbeach Colliery. Dr. Groom, by admitting the existence of 'a gentle unconformity at the base of the Coal Measures,' invalidated his own objections to the speaker's interpretation of the structure. As a fact, the attitude of the Lower Carboniferous strata determined a change from slight discordance with the Coal Measures on the northern edge of the coalfield to pronounced discordance on the eastern edge. The features in the Blackpool Valley were due, not to faulting as maintained by Dr. Groom, but to rapid, unconformable overstep by the Coal Measures. A mass of further evidence, collected by the speaker since 1912, could be adduced to confirm his reading of the succession in the Forest of Dean; but, on account of the lateness of the hour, he would not pursue the subject further.

[August 20th, 1918.]

7. *The* Trias *of* New Zealand. By Charles Taylor Trechmann, D.Sc., F.G.S. (Read February 7th, 1917.)

[Plates XVII–XXV—Fossils.]

Contents.

I. Introduction.

New Zealand occupies the most isolated and, so far as the palæontology is concerned, one of the lesser-known links in the great chain of folded marine Triassic sedimentary rocks which surrounds the Pacific Ocean.

The presence of Triassic rocks of the Alpine type in New Zealand was first made known as a result of the visit of the Austrian frigate 'Novara' in 1858 & 1859 and the researches of F. von Hochstetter. Four species of Triassic fossils found on that occasion were described and figured by Zittel in 1864.[1] These were *Monotis salinaria* var. *richmondiana* Zittel, *Spirigera wreyi* Suess, *Mytilus problematicus* Zittel, and *Halobia lommeli* Wissmann.

The Nelson province was the only district where Hochstetter obtained Trias fossils. He collected several Jurassic forms at Kawhia Harbour on the western coast of the North Island, but the Triassic deposits south of the harbour were discovered at a later date.

Since Hochstetter's visit the detailed geological survey of New

[1] Bibliography, 51, pp. 26–29.

Zealand has revealed the wide extension of the Triassic rocks, and their stratigraphical and tectonic features have in many areas been more or less satisfactorily worked out.

Sir James Hector[1] published from time to time lists of the fossils which the officers of the Survey had collected. His lists were not accompanied by figures or descriptions, and those from the beds with which the present paper deals were mostly names of well-known European Permian and Triassic forms. He paid, however, a closer attention to belemnites and brachiopods, and established three subgenera of the latter: namely, *Rastelligera*, *Psioidea*, and *Clavigera*, based upon descriptions unaccompanied by figures.[2] He caused plates illustrative of these groups to be printed, apparently intending them to accompany a longer paper which seems never to have been written. These plates have recently been issued with the First Palæontological Bulletin of the New Zealand Geological Survey,[3] and several of the fossils represented have been identified in the Survey collections. Hector's three brachiopod subgenera figure largely in the reports of his colleagues on the Survey; but their validity is not generally recognized outside New Zealand, nor by all geologists in that country.

Little has been done since then towards an accurate determination or description of the Triassic and Jurassic fossils, largely, no doubt, owing to the lack in New Zealand of literature dealing with the marine Trias of other regions. Prof. P. Marshall[4] in 1908 published a description with illustrations of six species of cephalopods, three from the Trias of the Hokonui Hills, and three from the Jura of Kawhia. The paper attracted the attention of G. Bœhm, the specimens were sent to him, and the result of his examination of them appeared in 1910.[5] A selection of fossils from the old Survey collections was sent to Bœhm, but was returned unexamined, owing to his death in 1910.

My interest in the Trias of New Zealand commenced during the British Association visit to Australasia in 1914, when I spent about nine weeks in the country. I was there again in 1915 and 1916, when I stayed three months, and again visited the chief Triassic and other fossiliferous localities and made extensive collections. I also had free access to the old Survey collections preserved in the Wellington Museum, some boxes of which had never been opened since they were collected over forty years ago. For this privilege I am indebted to Dr. P. G. Morgan, the Director of the Survey, and to Dr. J. Allan Thomson, the Curator of the Dominion Museum. A number of selected specimens were sent to England for me to examine. Prof. Marshall also kindly lent to me several fossils which he had collected in the Triassic and other rocks.

Special attention was paid to the collection of casts and impressions from which gutta-percha squeezes could be made, and I have largely

[1] Bibliography, 15, Introduction, p. x.
[2] Bibliography, 16.
[3] Bibliography, 47, pls. i–v.
[4] Bibliography, 25.
[5] Bibliography, 7.

used this substance during my work on the Triassic fossils, which are often unsatisfactorily preserved.

In the present paper forty-six genera of mollusca and brachiopoda are described, of which three seem to be hitherto undescribed and are regarded as new, and seventy-eight species, of which forty-one seem to be new, together with five or six new or local varieties of species already known. This certainly falls considerably short of the total which must exist in the New Zealand Trias. There are several conspicuous fossils which are too badly preserved, or otherwise unsuitable, for adequate illustration or description; but I hope that in the future better-preserved specimens of these and other forms may be found.

For the zonal divisions I have relied primarily on my own collecting; but, where better specimens than those that I found existed in the Survey collections, I have made use of these for description, though in most cases only where the recorded localities are confirmed by my own collecting.

II. Nomenclature and Correlation.

Great divergence of opinion has existed among New Zealand geologists concerning the classification of the rock series intermediate between the Reefton and Baton-River Series, which contain a marine Silurian or Devonian fauna, and the beds commencing with the Bastion Series which yield a lower Jurassic marine fauna. Hector classified them as follows in 1886 in his 'Handbook of New Zealand Geology.' In the right-hand column I add the equivalents which I suppose these divisions to represent, after my examination of the faunas.

Jurassic.	8 *a*. Mataura Series. 8 *b*. Putataka Series. 8 *c*. Flag-Hill Series.	Higher Jurassic series, with marine faunas as high as the Tithonian.	
Lias.	9 *a*. Catlin's-River Series. 9 *b*. Bastion Series.	Lower Jurassic beds, with marine faunas of Liassic, and probably also of Bajocian age.	
Trias.	10 *a*. Otapiri Series. 10 *b*. Wairoa Series.	=Rhætic and Upper Noric beds. =Lower Noric and Higher Carnic beds.	
Permian.	11 *a*. Oreti Series. 11 *b*. Kaihiku Series.	=Lower Carnic beds. =Beds with a Ladino-Carnic marine fossil horizon near the top, and a great thickness of unfossiliferous beds below, representing Middle and possibly Lower Trias.	
Carboniferous.	12 *a*. Maitai Series. 12 *b*. Maitai Limestones.	=Maitai Argillites, with *Aphanaia* De Koninck. =Maitai Limestone, with brachiopods, etc.	Permo-Carboniferous.
Devonian.	13 *a*. Te Anau Series. 13 *b*. Kakanui Series.	Probably in part metamorphosed Maitai Beds.	
Upper Silurian.	14 *a*. Baton-River Series. 14 *b* & *c*. Limestones and serpentine.	Silurian or Devonian, horizon not yet determined. Limestones with marine fauna.	

F. W. Hutton[1] in 1885 included the Te Anau and the Maitai

[1] Q. J. G. S. vol. xli (1885) pp. 191–220.

in his Maitai Series as Carboniferous and the Kaihiku, Oreti, Wairoa, and Otapiri in the lower part of his Hokonui System as Triassic.

Prof. James Park[1] in 1903 classed Hutton's Maitai Series as Jurassic. However, in 1910[2] he changed his opinion, and said that the evidence of the separation of the Te Anau from the Maitai was far from satisfactory, classing the Maitai limestone as Carboniferous. He also identified the Kaihiku as Permian and the Wairoa and Otapiri as Triassic, and included all the rocks from the upper part of the Maitai to the top of the Jurassic in his Hokonui System.

Prof. Patrick Marshall[3] in 1911 included all the beds, from Hutton's Maitai Series inclusive to the top of the Jurassic, in his Maitai System, and called them Trias-Jura, regarding them as a conformable series. The inclusion in recent years of the Maitai Series in the Trias-Jura or Jurassic is due to the fact that, since the survey of the Nelson area in 1878, no one had succeeded in finding either the Palæozoic fossils which occur in the Maitai Limestone of the Wairoa Gorge, or the large prismatic *Inoceramus*-like bivalves which exist in the Maitai Argillites at Wooded Peak, 5 miles east of Nelson and elsewhere. Fragments of this prismatic shell occur also in the Maitai Limestone, and led to the assumption that the rocks containing it were Jurassic. In the Nelson area the Trias is evidently separated from the Maitai Series which bounds it on the east and south-east by a strike-fault or series of faults, and the Maitai Series is undoubtedly of late Palæozoic age, as the early surveyors concluded.[4]

Hector's identification of many of the New Zealand Triassic fossils with English Permian Zechstein forms led him to place the Kaihiku and Oreti Series in the Permian, a conclusion which was naturally followed by his field-workers on the Survey. He identified three English Permian species out of a total of seventeen in the Kaihiku, three out of seven in the Oreti, one out of fourteen in the Wairoa, and four out of nineteen in the Otapiri. However, in the Wairoa and Otapiri Series he records, in addition to his supposed Permian forms, a number of Alpine Triassic fossils. The following reasons seem to have caused Hector to class the Kaihiku beds as Permian:—

[1] Bibliography, 40, p. 431. [2] Bibliography, 37, p. 51.

[3] Bibliography, 22, p. 22.

[4] C. T. Trechmann, Geol. Mag. dec. 6, vol. iv (1917) pp. 53–64. Dr. J. A. Thomson and I were so fortunate as to rediscover in 1915 the fossils in the Maitai Limestone, and to obtain a few additional unrecorded forms from it: they are undoubtedly of Permo-Carboniferous age. I also found the large prismatic bivalves in the Maitai Argillites at Wooded Peak, and have shown from examination of the hinges that they are not *Inoceramus*, but are apparently identical with *Aphanaia* De Koninck of the Australian Permo-Carboniferous. The Permo-Carboniferous of New Zealand differs from that of Australia in being apparently entirely marine, and in lacking a *Glossopteris* flora and glacial beds.

A. A *Dielasma* closely resembling the Permian *D. elongata* occurs in them.

B. He identified the Rhynchonellids of the *Halorella* group with the Permian genus *Camarophoria*.

C. He compared the alate *Spiriferinæ* with the Permian *Spirifer alatus*, which is not a *Spiriferina*, but a true *Spirifer* devoid of punctate shell or median dorsal septum. Even Prof. C. Diener was not certain on this point, and speaks of *Spiriferina alata*.[1] The error is due to King, but was corrected by Davidson.

D. The *Spiriferinæ* of the group of *Sp. fragilis* bear a certain resemblance to the Permian *Spiriferina cristata*.

E. The flat dorsal valve of a spiny *Mentzelia*, to which I have given the generic name *Mentzeliopsis*, seems to have suggested to Hector the genus *Streptorhynchus*, which appears in his list of Kaihiku fossils. I myself thought when I collected it that it was some Palæozoic survival, until, after I had ground down a specimen with both valves conjoined, the spiralia in it became apparent.

Hector and others sometimes speak of the whole or part of the Otapiri Series as Rhætic. As there is apparently a perfectly conformable passage from the Wairoa to the Bastion Series, the intermediate beds may by analogy be called Rhætic. But, on an examination of the fossils, the correlation seems to be valid also on palæontological grounds. The large specialized Spirigerid to which I have given the new generic name *Hectoria* shows decided affinities with the Alpine Rhætic form *Spirigera oxycolpos* Emmrich, the largest and latest of the Alpine Spirigerids.

Briefly stated, the following are the points in which the results of my work contrast with the previous views on these beds:—

a. The great unfossiliferous series beneath the lowest fossiliferous horizon in the Kaihiku represents the Middle and possibly part of the Lower Trias. It is possible, though very unlikely, that some fossils will in future be found in the Kaihiku Series below the above-mentioned horizon.

b. The Kaihiku fauna, the lowest fossiliferous Mesozoic horizon in New Zealand, is either Upper Ladinic or Lower Carnic—that is, late Middle or early Upper Trias, and not Permian, as was hitherto supposed.

c. The higher fossiliferous horizons, which are always separated in clear sections by several hundred feet from that of the Kaihiku, are all Upper Trias. The Oreti and lower part of the Wairoa are Carnic, and yield a prolific fauna. The upper part of the Wairoa and lower part of the Otapiri are Noric, and contain *Pseudomonotis* in great abundance. The remainder of the Otapiri is Rhætic.

d. The only forms that seem to survive the Trias, and may be identical with Triassic species, are a form of the Spirigerid genus *Hectoria* and some of the belemnites of the *Atractites* group, the large phragmocones of which occur in the Jurassic beds.

e. I found no fossil in the New Zealand Trias that could be identified with any English Permian species, so many of which occur in Hector's lists.

f. I can see no reason why any of the New Zealand Triassic forms should be regarded as local isolated survivals from Palæozoic times, as has sometimes been suggested.[2] The fauna is a normal Upper Triassic one,

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[1] Bibliography, 11, p. 2. [2] Bibliography, 37, p. 69.

comparable in every way with faunas of similar age in the great circum-Pacific region. It is now well established that *Trigonia* and belemnites of the *Atractites* and *Aulacoceras* group are normal associates in the marine Triassic beds with such Palæozoic survivors as *Orthoceras* and *Dielasma*. It is the association of Palæozoic survivals with the Mesozoic forerunners which gives a special interest to the Trias. Such archaic survivors at the present day as exist in New Zealand are chiefly found in the terrestrial fauna and flora owing to its long isolation as a land-mass.

g. There is no premature appearance of truly Jurassic forms in the New Zealand Trias. The supposed *Gryphæa*[1] which has been mentioned in this connexion is a shell allied to that called *Mytilus problematicus*.

III. Lithology, Thickness, and Tectonics.

The Trias consists of a great series of coarse or fine felspathic sandstones, grey or dark shales, and argillites—some very hard, others, when weathered, of a splintery or crumbling nature, frequently enclosing concretions. Thick beds of coarse conglomerate, more or less discontinuous and lenticular, appear at various horizons. Thin bands of pebbles also occur in the felspathic sandstones and greywackes. Prof. Marshall[2] has examined the pebbles composing some of the conglomerates, and notes the absence of schistose rocks. They are made up of granitic or porphyritic fragments with felspar- and quartz-pebbles.

The Rhætic beds become more pebbly and glauconitic and less felspathic, approaching in character the overlying Jurassic series. In some beds the quantity of felspar is so great that the rock weathers along the joint-planes in large spheroidal masses, and has given rise to the term 'cannon-ball sandstone.' Iron-stained beds containing plant-remains occur interbedded with the marine series at several places.

No definite assertion can yet be made as to the source whence the material of the Trias was derived, but there was evidently some large land-mass not far away. The series seems to agree closely with the littoral facies of the Trias on the south-western coast of New Caledonia. The littoral nature of the sediments explains the absence or rarity of certain fossils, such as ammonites and corals. Except in the Okuku district, where diabasic ash-beds are reported to occur (but these, if re-examined, would probably turn out to be felspathic sediments), no contemporaneous igneous rocks are known in the Trias. A dyke occurs at Nugget Point,[3] and a hypabyssal intrusion at Kawhia[4]; but these are probably of post-Jurassic age.

No natural base of the Trias is seen in any of the localities described, although in the Takitimu Mountains, west of the Hokonuis, the Kaihiku is said to rest unconformably upon the Maitai Series.[5]

[1] Bibliography, 22, p. 22.
[2] Bibliography, 23.
[3] Bibliography, 45.
[4] Bibliography, 30.
[5] Bibliography, 15, Introduction, p. xii.

Prof. Marshall estimates the thickness of the rocks from the top of the Baton-River Series to the top of the Jurassic, his Maitai System, at 53,200 feet. This includes the Upper Palæozoic, Triassic, and Jurassic strata. Prof. Park reckons the thickness of the Trias and Jura at 18,000 feet. When I was at Nugget Point I stepped out the series of the fossiliferous Trias exposed there, from the Rhætic beds northwards to the road leading to the lighthouse where the Kaihiku fauna is said to occur. The beds are tilted on end, and the section is clear; but the Noric *Pseudomonotis* Beds are missing. I estimated the thickness at well over 3000 feet. Prof. Park's diagram of the Nugget-Point section includes a part of the unfossiliferous Kaihiku and all the fossiliferous Trias, and the thickness is about a mile. At Kawhia the Rhætic alone is over 3000 feet thick.

All rocks in New Zealand older than the Cretaceous are affected by the great orogenic pressure which occurred between the uppermost Jurassic and the Middle Cretaceous.[1] The Trias, except on the west side of the Hokonui Hills and immediately south of Kawhia, stands everywhere nearly or quite vertical. The Jurassic beds, as a rule, dip much less steeply. The schistosity of much of the metamorphic rock of the Southern Alps appears to have been produced during this period. Some of these metamorphic and semi-metamorphic rocks are undoubtedly Mesozoic, others are Maitai or pre-Maitai. Greywackes associated with the Trias pass gradually into phyllites and schists. The change has been described by Prof. Marshall,[2] who states further that the schists pass gradually into the gneisses of Westland. The semi-metamorphic slaty argillites at Mount St. Mary, which are full of crushed and distorted Triassic fossils of Kaihiku or Ladino-Carnic age, contain secondary macroscopic flakes of white mica parallel to the foliation.

[1] The history of New Zealand as a land-surface dates from about the time of the final break-up of Gondwanaland, and its uplift may be connected with that event. In connexion with the age of the Maitai Series, I have shown that the New Zealand area was under water during the Permo-Carboniferous Period. The Jura-Cretaceous uplift is not connected with the present configuration of New Zealand, except that the rocks then hardened and metamorphosed resist weathering better, and now form the Alpine Ranges. It was probably reduced to a low elevation before late Cretaceous times. No part of the present New Zealand can be said with certainty to have remained land during Tertiary times. The present uplift dates from the Middle or late Tertiary, and was more of an epeirogenic nature accompanied by block-fracture. Tertiary strata are deeply involved in faults, overthrusts, and downthrows in the Alpine and other areas, but in no case are they much crushed or metamorphosed.

[2] Bibliography, 21, p. 21.

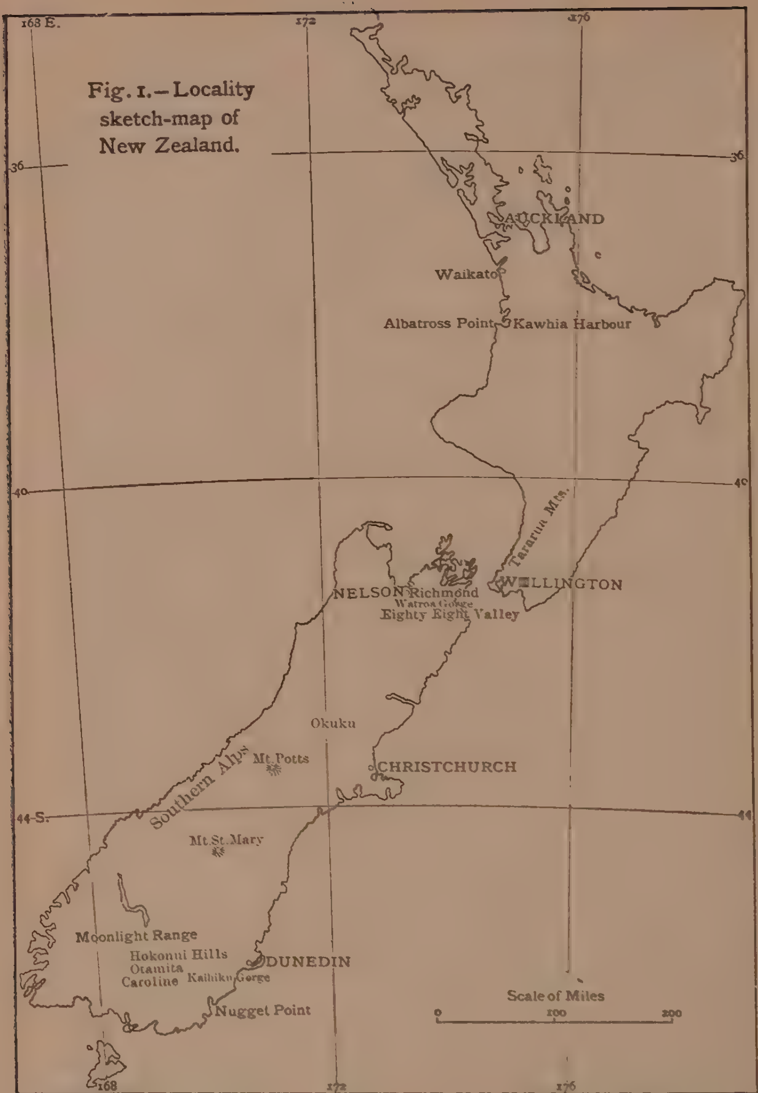


Fig. 1.—Locality sketch-map of New Zealand.

At Kawhia, on the western coast of the North Island, folded Triassic and Jurassic rocks are exposed beneath horizontal Tertiary covering deposits. At Waikato Jurassic of undetermined age occurs. Only the Rhætic and Noric beds of the Trias are known as yet in the North Island.

In the South Island, in the Nelson district, the Trias is much faulted and folded, and strikes more or less north-north-eastwards and south-south-westwards - parallel to the main structural axis. In the far south it is much less faulted and disturbed, and the strike of the Trias and Jura from the Hokonui Hills past Kaihiku Gorge to the coast at Nugget Point is approximately west and east to west and south-east, at right angles to the strike in

IV. Typical Areas of Triassic Rocks.

Fossiliferous Triassic beds are exposed at intervals, from Kawhia on the western coast of the North Island to Nugget Point on the south-eastern coast of the South Island, a distance of 620 miles or nearly 9° along the meridian. The most important localities are briefly described in the following order:—

District.	*Chief fossiliferous localities and the horizons represented.*
North Island.	
Kawhia.	Coast-section south and south-west of Kawhia Harbour, towards Albatross Point (Noric and Rhætic).
South Island.	
Nelson area.	Richmond (Noric); Wairoa Gorge (Carnic); Garden Gully (Carnic and Noric); Mount Heslington (Carnic); Eighty-Eight Valley (Kaihiku or Ladino-Carnic and Carnic).
Okuku.	Carnic, Noric (?).
Mount Potts.	Kaihiku or Ladino-Carnic, and Lower Carnic.
Mount St. Mary.	Kaihiku or Ladino-Carnic, and possibly Lower Carnic.
Hokonui Hills: North side.	Gore (Carnic, Noric); Otamita (Carnic, Noric); East Peak (Kaihiku or Ladino-Carnic).
South-west side.	Caroline railway-cutting (Kaihiku or Ladino-Carnic); Benmore Cutting (Rhætic).
Kaihiku Gorge.	Kaihiku or Ladino-Carnic, Carnic, Noric.
Nugget Point.	Kaihiku or Ladino-Carnic, Carnic, Rhætic.
Moonlight Range.	Carnic, Noric.

The localities in the South Island are probably connected along the structural axis by others where the fossils are still undiscovered, or have been more or less obliterated through metamorphism.

North Island.

Kawhia.

The Jurassic strata are well exposed round the shores of Kawhia Harbour, where they lie unconformably beneath a horizontal cover of Tertiary limestones, and Kawhia is the most important locality in the North Island for Jurassic fossils. Outside the harbour in

the Nelson district. At Mount Potts and Mount St. Mary the Triassic beds form part of the eastern fringe of the complex of the Alpine Range, and are crushed and partly metamorphosed. Except immediately south-west of Kawhia Harbour, and on the southern and western side of the Hokonui Hills, the Triassic beds stand everywhere practically vertical.

At Kawhia, and in the far south, the Trias is succeeded conformably by Jurassic rocks. At Nelson and in the Alpine Region no Jurassic is known. In the Nelson district fossiliferous Trias, from the Ladino-Carnic to the Noric inclusive, occurs. The Triassic limestones at Okuku are of uncertain age, but probably Carnic. At Mount Potts and Mount St. Mary the Ladino-Carnic (Kaihiku) and possibly Lower Carnic occur. In the ranges extending from the Hokonui Hills to Nugget Point all divisions, from the Kaihiku to the Rhætic inclusive, are fossiliferous, and the overlying Jurassic is also highly fossiliferous.

the coast-section extending southwards and south-westwards the Jurassic deposits pass conformably down into a thick series of grey felspathic sandstones with bands of pebbles and conglomerate-beds. These beds gradually become increasingly inclined until Tarawai Point, north of Albatross Point, is reached. Fossils are scarce, but quite high up in these beds Prof. Marshall and I found a specimen of *Arcestes* cf. *rhæticus*, and a little lower down another similar but indeterminable *Arcestes*. Brachiopods occur sparingly, generally in little clusters throughout a great thickness of these rocks. The commonest form is *Hectoria bisulcata*, and rather high up (but below the *Arcestes*) I found two specimens of *Mentzelia*. These beds are presumably Rhætic.

At Tarawai Point, some miles south of Kawhia Harbour, there is a large intrusion of a hypabyssal porphyry of the syenite group, and the sedimentary rocks are here nearly or quite vertical. A black argillite full of *Pseudomonotis ochotica* and its varieties occurs in very close association with this intrusion, and seems in places to underlie and become involved in it. Great masses of this dark shale are found mixed up with blocks of porphyry lying on the shore. These beds are Noric, and are the lowest Trias that I saw in this locality. McKay,[1] in a sketch-map appended to his report of the district, shows a repetition of the Wairoa, Otapiri, and Bastion Series south of the igneous intrusion, but says that the rocks were not examined. Prof. Marshall, who on a previous occasion visited that very rugged portion of the coast in a boat, tells me that he saw no fossils there.

South Island.

Nelson Area.

The strip of fossiliferous Trias in this district extends in a north-easterly and south-westerly direction from near Richmond to Eighty-Eight Valley, a distance of about 12 miles. Its greatest width is about three-quarters of a mile, near the Wairoa Gorge. The beds are steeply inclined. Various sections have been drawn to show the arrangement of the beds, but the structure is complicated and involved. Great divergence of opinion exists regarding the presence or absence of faults, and the relation of the Trias of the foothills to the Maitai Limestones and Argillites which form the higher peaks that bound it on the south-east. In the Wairoa Gorge the Maitai Limestone contains an Upper Palæozoic fauna, and closely adjoins the dark greywackes full of *Mytilus problematicus*. At Richmond the felspathic sandstones containing *Pseudomonotis richmondiana* are sharply cut off on the east by unfossiliferous red and green slaty argillites of the Maitai Series.

The Kaihiku Beds appear only in Eighty-Eight Valley at the south-western end of the Triassic outcrop. Here they are wedged in between Maitai Limestone on the south-east and the Upper

[1] Bibliography, 30.

Trias on the north-west. The strip of Kaihiku Beds is half a mile long and a quarter of a mile wide, and the strata dip south-south-eastwards at 55° to 65°.

In the Wairoa Gorge the *Mytilus-problematicus* Bed occurs near the entrance, and again on the east close to the Maitai Limestone. The intervening space is occupied by the higher beds of the Carnic.

In the hills south of the gorge the *Pseudomonotis-richmondiana* Beds occur in full thickness, but are not seen in the gorge itself. At Garden Gully, about a mile south-west of the Wairoa Gorge, I found a bed of fine-grained greywacke containing many varieties of the Asiatic Noric fossil *Pseudomonotis ochotica*. It seems to occupy the limb of a syncline, possibly a faulted syncline, and I believe the Noric *Pseudomonotis-ochotica* Beds to be the highest that occur in the Nelson area.

No Jurassic fossils have been found in this part of the South Island. All the evidence that I saw led me to conclude, in opposition to recent Survey results,[1] that there is a series of strike-faults parallel to the structural axis and that the Trias is partly overthrust to the north-west by the Maitai Series. The Tertiary deposits of the Waimea Plains, which bound the Trias on the north-west, are tilted up along their junction, and are probably overthrust to some extent in their turn by the Trias.

Okuku (Ashley County).

The geology of this very mountainous district is little known. McKay studied and described it in 1879,[2] and states that the whole of the northern end of the Mount-Torlesse range is occupied by Trias and younger formations, which form the higher peaks of Mount Torlesse. The rocks consist of a great thickness of conglomerates, sandstones, red and green so-called 'diabasic ash' (by which one may probably understand coarse greywacke), and limestones. *Mytilus problematicus* and *Monotis salinaria* are said to occur in the limestones and in the 'diabasic ash.' These fossils are found in immense numbers in the Upper Okuku Valley, in a limestone associated with cherts. I had no opportunity of visiting this locality, and McKay's report is not quite clear as to whether the *Monotis* and *Mytilus* occur together or in separate strata. I examined a series of the *Monotis*-like shells in the limestone from this district belonging to the New Zealand Geological Survey, and selected several examples to be sent to England. These pieces of limestone contain *Monotis*, but no *Mytilus*. I could find no trace of the anterior byssal notch characteristic of *Pseudomonotis* in any of these shells, and therefore am compelled to regard them as really the Alpine *Monotis salinaria*. If this be the case, their reported association with *Mytilus problematicus* may be explicable, as *Monotis salinaria* is recorded from Carnic horizons in Europe. Perhaps future research in the district may clear up these points.

[1] Bibliography, 22, pp. 20–22.

[2] Bibliography, 29.

Mount Potts.

The chief interest of this locality centres in the plant-beds discovered by McKay in 1877. Great uncertainty has arisen over the age of these beds and the associated marine fossils, owing to Hector's determination of *Glossopteris* among the flora. The district, which is extremely mountainous, was described by McKay,[1] who states that the plant-beds of Tank Gully underlie the marine '*Spirifer*' Beds. Later, however, he says that plant-remains overlie the Kaihiku in the district between the Rangitata and Ashburton Rivers.[2] The fossils in the marine beds have been variously determined as Permian, Lower Carboniferous, or Upper Devonian; but my examination of the Geological Survey Collection and of a series collected by Prof. Marshall convinced me that they are all Triassic. They occur in black, compressed and fractured, slaty argillites. The following forms are present:—

A Nautilid.
Small gasteropods with angular whorls.
Daonella indica Bittner.
Pinna sp.
Anodontophora sp.
Spirigera kaihikuana, sp. nov.
Spiriferina (Cyrtina?) carolinæ, sp. nov.
Spiriferina sp.
Halorella sp.
Dielasma sp.
Mentzeliopsis sp.
Crinoid-stems.

Mr. McKay told me that *Mytilus problematicus* occurs there, but there is no trace of *Monotis* or *Pseudomonotis*.

The great majority of the fossils are those of the Kaihiku and are of early Upper or late Middle Trias. The only forms that indicate a Carnic horizon are *Nautilus* and *Pinna*. Reptilian remains occur in some of the beds, the large narrow amphicœlous vertebræ of which suggest some form of *Ichthyosaurus*.

The late Dr. E. A. N. Arber[3] examined a series of the plants which Mr. D. G. Lillie collected here in 1911, with the result that the supposed *Glossopteris* turned out to be a new form, to which he gave the generic name *Linguifolium*, and the whole flora proved to be either late Triassic, Rhætic, or early Jurassic. Dr. Arber, however, informed me that, at present, it is impossible to distinguish between late Triassic and early Jurassic floras. From the evidence, both of the flora and of the associated marine fauna, it seems perfectly justifiable to attribute an Upper Triassic age to the plant-beds of Mount Potts; but the question as to the position of the plant-beds relatively to the marine horizon is one on which further evidence is needed.

Mount St. Mary.

The fossiliferous outcrop at Mount St. Mary occurs at an altitude of 5160 feet. Fossils occur in three zones in a thickness of 50 feet: the two lower zones are slaty shales and the upper a

[1] Bibliography, 28, p. 92. [2] Bibliography, 28, p. 95.
[3] Bibliography, 2.

conglomerate. The fossiliferous rocks are associated with altered sandstones, and follow the phyllites, quartzites, etc. (known as the Kurow Schists) in direct stratigraphical succession. At the foot of the mountain the dip is very high, and at the fossiliferous outcrop it is about 60°. Prof. Park[1] says that the thickness of the strata exposed in the section is not less than 10,000 feet, and he gives a careful enumeration of these metamorphic and semi-metamorphic rocks. His attribution, however, of a Permo-Carboniferous age to the fossils is erroneous, as they are all Triassic, and the majority belong (as do those at Mount Potts) to the Kaihiku Series. I examined the series in the Geological Survey Collection, and also a collection which Prof. Marshall made. Many of the forms attain an unusually large size, but are much crushed and distorted: they occur in a fissile slaty argillite or greywacke. I identified the following forms:—

A crushed Nautilid.
Patella (?), crushed.
Pleurotomaria sp. and another small gasteropod.
Lima sp.
Part of a large indeterminate bivalve.
Many small specimens of *Megalodon* cf. *globularis*, sp. nov. in a coarse, gritty felspathic sandstone.
Spirigera resembling *Sp. kaihikuana*, sp. nov.
Mentzeliopsis sp. of unusually large size.
Large alate *Spiriferinæ* and a small form resembling *Spiriferina fragilis* Schlotheim.
Large *Dielasma*.

There is no trace in this fauna of *Hectoria*, *Halobia*, *Mytilus*, or *Pseudomonotis*.

It is quite certain that the slaty shales contain the Kaihiku fauna, and are of late Middle or early Upper Triassic age, while the *Megalodon*-like bivalves in the higher conglomerate-bed suggest the presence of part of the Carnic horizon below the *Mytilus-problematicus* Bed.

Hokonui Hills.

The Hokonui Ranges consist of a series of conformable Triassic and Jurassic rocks. On the north-east they are bounded by the Waimea Plains and the Waimea River, a tributary of the Mataura, and on the south-west and south-east by the Makerewa Flats and the Oreti River. Their structure was investigated by S. H. Cox[2] and A. McKay[3] in 1878. The hills rise to a height of about 2500 feet, and are part of a range extending from the Takitimu Mountains to Nugget Point on the south-eastern coast of Otago. The Government surveyors estimated the thickness of the strata at 21,000 feet or more. The structure is roughly that of a trough, of which only the northern and western edges are exposed. The axis follows roughly a south-easterly trend at its western end and a nearly easterly trend at the eastern end. The beds along the northern and north-eastern fringe of the hills stand nearly vertical, while on the southern and western side the dip rapidly decreases

[1] Bibliography, 38. [2] Bibliography, 9. [3] Bibliography, 27.

till they form a flat syncline with an axis oriented north-west and south-east. The result is that the outcrop of the beds bends round, and becomes much wider on the south-western side. In consequence, the Triassic rocks occupy the northern and western fringes of the hills; while the inner and less accessible part of the range, together with the southern and south-western portion, is occupied by the much less strongly inclined Jurassic deposits.

The great mass of greywackes and conglomerates, called the Kaihiku Series, estimated as 6600 feet thick, occupies the northern fringe. The thin fossiliferous band, which occurs 4000 feet above the lowest beds seen in the district, crops out at various points as a continuous bed. It is seen in a railway-cutting a mile south of Caroline Station, and at East Peak, whence it extends eastwards in the direction of the Kaihiku Gorge, from which it takes its name, and finally reaches the coast at Nugget Point.

I visited various localities in the Hokonuis in company with Prof. Marshall, but most of our collecting was done at a spot, previously known to Prof. Marshall, in the valley of the Otamita Stream some distance west of East Peak. This stream, according to the map published by Cox & McKay, flows eastwards in the first part of its course approximately down the junction of the Otapiri and Upper Wairoa Series. It then turns northwards and cuts across the strike of the Lower Wairoa and Kaihiku Series, ultimately joining the Mataura. The section that we observed on both banks of the Otamita Stream is as follows:—

Beds.	*Approximate thickness in feet.*	*Fossils.*	*Age.*
a. Massive felspathic grits and sandstones.	20	Fragment of *Pinacoceras*, alate *Spiriferinæ*.	? NORIC.
b. Felspathic sandstones interbedded with shaly bands.	20	*Nautili*, *Arcestes*, *Discophyllites*, *Halobia hochstetteri*, etc.	CARNIC.
c. A massive bed of dark, hard, but fissile crumbling shale, with concretionary nodules in its lower part.	25	*Halobia hochstetteri* and many other well-preserved fossils, *Nautili*, *Discophyllites*.	
d. Felspathic sandstones and argillites.	?	*Pleurophorus*, *Spiriferina*, etc., badly preserved.	
e. Dark-grey rusty shales with small rounded pyrite nodules, and bands of felspathic sandstone weathering in spheroidal masses.	100	*Halobia zitteli* var. *zealandica*, *Spirigera manzavinioides*, *Spiriferinæ*, *Conularia*, and many other fossils.	
f. Dark slaty shales.	?	Full of *Mytilus problematicus*.	

Fossils are unusually well preserved in beds *c* and *e*. The Geological Survey reports make no mention of the occurrence of *Mytilus problematicus* in the Hokonui Hills, and so it would appear that this section was overlooked by the Government surveyors in 1878.

Kaihiku Gorge.

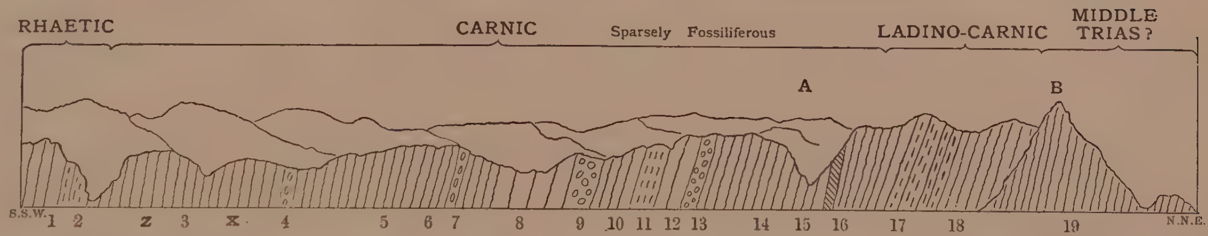
This gorge cuts across the strike of the Triassic range between the Hokonui Hills and Nugget Point. At the entrance of the gorge several blocks fallen from the rock that crops out on the grassy hillside, but is not well exposed, contain the fauna which takes its name from the locality. The fauna, a very constant one, corresponds exactly to that found at various points in the Hokonuis and at Eighty-Eight Valley, near Nelson. Some distance above this a thick coarse conglomerate occurs, overlain by a hard greywacke full of indeterminable plant-remains. A thick series of spheroidal felspathic sandstones represent the Wairoa and Otapiri Beds, but fossils are very scanty. In the stream I found a piece of a *Pinacoceras*, evidently washed down from the higher Triassic beds.

Nugget Point.

This is one of the clearest sections of the Trias in New Zealand. In Roaring Bay or Shaw Bay, south of Nugget Point Lighthouse, the beds are ranged almost vertically for a distance of nearly a mile. It is possible to obtain a good idea of the thickness and succession of the fossiliferous Trias. Here, however, although the Carnic with the *Mytilus-problematicus* Bed is well developed, the *Pseudomonotis* Beds of the Noric are missing. The series commences with hard unfossiliferous greywackes and felspathic sandstones, upon which the lighthouse stands. Slightly south of this, Prof. Park tells me that fossiliferous bands in the Kaihiku Series occur, although I did not succeed in finding them. The Carnic Series is excellently developed, and yields many fossils, showing several recognizable zones. About 195 feet above the *Mytilus-problematicus* Bed is a band of ferruginous sandstone with fragmentary plant-remains, where I collected a fragment of a frond which I identified as *Thinnfeldia* cf. *odontopteroides* Morris.[1] The late Dr. E. A. N. Arber kindly confirmed this identification, and informed me that this species is commonest in the Upper Trias, although not confined to that horizon. The Noric is not recognizable here; but Prof. Marshall has recently traced it at Glenomaru, about 10 miles inland from Nugget Point. A fragment of the rock that he sent me is full apparently of the small rounded and arched variety of *Pseudomonotis richmondiana*. The Triassic System comes to an end, about a mile south of the lighthouse, with a hard, resistant, pebbly and glauconitic or chloritic felspathic conglomerate, full of *Hectoria* (*Clavigera*) *bisulcata*

[1] Now in the Sedgwick Museum, Cambridge.

Fig. 2.—*Diagrammatic section of Triassic deposits from South Head, Shaw Bay to Nugget Point.*



1. Claystones and sandstones.
2. Pebbly sandstones, with *Hectoria bisulcata* and *Spiriferina diomedea*.
3. Coarse sandstones.
4. *Mytilus-problematicus* Bed.
5. Claystones and sandstones.
6. So-called '*Trigonia*' Bed.
7. Granite conglomerate.
8. Sandstones and claystones.
9. Conglomerate.
10. Greywackes and sandstones.
11. Greywacke.
12. Indurated claystones.
13. Conglomerate.
14. Greywackes and sandstones.
15. Claystones and greywackes.
16. Dyke of porphyrite.
17. Greywacke and sandstone.
18. Black *Spiriferina* claystones (Kaihiku fossiliferous band).
19. Claystones (plant-beds, according to Prof. Park).

z. Position of *Halobia zitteli* var. *zealandica* and *Palæocardita*; slightly north of this a bed containing *Clydonautilus*, *Pleurophorus*, and other fossils occurs.

x. Ferruginous sandstone with *Thinnfeldia odontopteroides*.

A. Track to Roaring Bay. B. Nugget-Point Lighthouse.

[The Noric *Pseudomonotis* Beds are missing in this section, which is about a mile long.]

and the very alate *Spiriferina diomedea*. The section was described by McKay, and later by Park. I confirmed the lithological sequence as Prof. Park[1] represents it, and have added in fig. 2 (p. 180) my interpretation of the zones represented after examining the fossils collected there.

Moorlight Range.

This lies more or less on the westward continuation of the Hokonui Hills, but the geology of the district is very little known. A considerable series of Triassic rocks is probably present there. In the Geological Survey Collection from this locality I identified the following forms: *Pseudomonotis richmondiana* Zittel, and a large flat form like *Ps. ochotica* Teller, var. *densistriata*, *Halorella* sp., and a small bivalve.

V. Palæontology.

CEPHALOPODA.

The Cephalopods of the New Zealand Trias belong to the genera *Orthoceras*, *Clydonautilus*, and *Grypoceras* among the Nautilids; *Aulacoceras*, among the Belemnoids; and among the Ammonites, *Arcestes*, *Cladiscites*, *Pinacoceras*, and *Discophyllites*. The last is the only ammonite sufficiently well preserved to afford any real zonal information. No cephalopods have been found in the Kaihiku Beds, and the Trias of New Zealand shares with that of New Caledonia and the Malay Archipelago the absence of ammonites of the Ceratitic type, or of the profuse Upper Triassic ammonite fauna which occurs in Western America and in the Himalayas.

Orthoceras sp. (Pl. XVII, fig. 6.)

Surface of the shell smooth; growth-lines straight, not sinuous. The septa are rather strongly convex towards the apex, and the siphuncle is slightly excentric. Length originally = about 40 mm.; diameter of aperture = 6 mm.; and length of living chamber = about 11 mm. The aperture of the latter is preserved, and is circular in outline, quite horizontal; the rim is slightly thickened. In the angle of emergence and other features it resembles *O. triadicum* Mojsisovics.

Locality and horizon.—The only locality that I know where this dwarfed *Orthoceras* occurs is Bed *c*, Otamita, Hokonui Hills, Carnic. Previous records of *Orthoceras* seem to have been based on parts of the phragmocones of large Atractitid belemnites.

Grypoceras cf. mesodiscum Hauer.

1902 E. von Mojsisovics, 'Cephalopoden der Hallstätter Kalke' vol. i, Supplem. p. 229.
1910. G. Bœhm, Centralblatt f. Min. &c. p. 635.

The name of *Nautilus mesodiscus* appears in Hector's list of

[1] Bibliography, 39, p. 382 & pl. xxix.

fossils of the Otapiri Series, and this attribution is confirmed by Diener on the strength of a specimen which Prof. Marshall sent to Bœhm. Several specimens of this shell that I collected confirm Diener's observations on the external ornamentation, which consists of longitudinal lines crossed by fine transverse lines. The sutures show a very shallow ventral lobe and similar, but rather deeper, lateral lobes, and a small, well-marked, annular lobe. The siphuncle in a specimen of three whorls occurs about midway between the centre and the ventral margin.

Locality and horizon.—Bed *c*, Otomita, Hokonui Hills; Nugget Point, and other localities. Carnic.

CLYDONAUTILUS (PROCLYDONAUTILUS) cf. SPIROLOBUS Dittmar. (Pl. XVII, fig. 3.)

1902. E. von Mojsisovics, 'Cephalopoden der Hallstätter Kalke' vol. i, Supplem. p. 211 & pl. x, fig. 3, pl. xi, fig. 1.
1910. G. Bœhm, Centralblatt f. Min. &c. p. 634.

A Nautilid with angular sutures was sent by Prof. Marshall to Bœhm, and handed on to Diener, who identified it as near the above species. In specimens that I collected the lobes are angular and the saddles rounded, strongly recalling those of a nearly-allied species *Pr. goniatites* Hauer. The siphuncle of a specimen of three whorls is dorsad of the centre. The surface of the shell slopes more towards the venter, and is less rounded than in either *Pr. spirolobus* or *Pr. goniatites*; while the venter itself is narrow and gently rounded.

Locality and horizon.—It is common in Bed *c*, Otamita (Hokonui Hills), and occurs also at Nugget Point and other localities.

ARCESTES sp.

1909. *Arcestes hokonui* P. Marshall, Trans. N.Z. Inst. vol. xli, p. 144.
1910. G. Bœhm, Centralblatt f. Min. &c. p. 634.

Arcestids are fairly common in the Carnic beds, especially in Bed *c* at Otamita. Prof. Marshall sent a specimen from this locality to Bœhm, who submitted it to Diener. As the living chamber was missing, he could not say whether it was *Arcestes* or *Proarcestes*, and considered it better not to give any specific name. No specimen that I saw or found had the living chamber, and so I cannot add anything to Diener's observations. If more complete specimens could be obtained, it would probably be found that several species of *Arcestes* are present in the New Zealand Trias.

ARCESTES cf. RHÆTICUS W. B. Clark. (Pl. XVII, fig. 1.)

1888. Am. Journ. Sci. ser. 3, vol. xxxv, p. 119.
1895. J. E. Pompeckj, 'Ammoniten des Rhät' Neues Jahrb. vol. ii, pt. 1, p. 3.

Shell smooth, sides and venter rounded, umbilicus wide and deep; the umbilical shoulders are rounded, and slope towards the

umbilicus. The living chamber is wanting; but on the last whorl two slightly-sinuous channels cross the venter and sides nearly opposite one another, and represent former contractions of the aperture.

This specimen agrees in outer shape with *Arcestes rhæticus*, a form for which Hyatt has proposed the new generic name *Rhætites*, but seems to differ in the sutures. Five saddles are seen between the siphuncular saddle and the umbilical shoulders, the fourth being higher up though not larger than the rest. The saddles are deeply cut on each side into four auxiliary saddles, and the siphonal lobe is divided by a saddle into two points which are not deeper than the lateral lobes. In *Arcestes rhæticus* the sutures are said to form a series of lobes and saddles which gradually decrease in size from the siphuncle, and the two siphuncular lobes are deeper than the lateral lobes.

Mojsisovics says that Pompeckj considered *Arcestes rhæticus* to be merely part of the inner whorl of an *Arcestes* of the Galeati group.

Locality and horizon.—The specimen illustrated in Pl. XVII was collected by Prof. Marshall and myself high up in the Rhætic between Kawhia Harbour and Albatross Point, 3000 feet or more above the Noric *Pseudomonotis* Beds. It is probably the highest Triassic fossil that we obtained in New Zealand: it is entirely distinct from the Arcestids in the Carnic, which are much smaller, more involute, and lack the deep funnel-shaped umbilicus.

CLADISCITES sp. (Pl. XVII, fig. 2.)

Sides flat, sloping gently towards the small shallow umbilicus; venter gently rounded. The living chamber is missing and the shell destroyed, and consequently it is impossible to see whether there was any surface decoration. No specific name can, therefore, be given.

Locality and horizon.—The only specimen of this genus known to me comes from the *Nautilus* Bed at Mount Heslington, Nelson. Carnic.

PINACOCERAS sp.

All the specimens of *Pinacoceras* that I saw are fragments of air-chambers, and no satisfactorily-preserved example has come to light. One cannot, therefore, say more than that this genus, or some similar large and flat phylogerontic form with very complicated sutures, occurs in the higher Triassic deposits.

Locality and horizon.—I found a fragment in a bed at Otamita, in the Hokonui Hills, which is probably Lower Noric; and in the Geological Survey Collection is a piece of a very large flat *Pinacoceras*, but with greatly eroded sutures, from beds on the eastern side of Mount Heslington, near Nelson, which may also be Lower Noric.

Discophyllites cf. ebneri Mojsisovics. (Pl. XVII, fig. 7.)

1896. *Phylloceras* (*Mojsvarites*) *ebneri* 'Obertriadische Cephalopodenfauna des Himalaya' Denkschr. k. Akad. Wissensch. Wien, vol. lxiii, p. 668 (96) & pl. xix, fig. 6.
1906. C. Diener, 'Fauna of the *Tropites* Limestone of Byans' Pal. Ind. ser. 15, vol. v, Mem. 1, p. 173 & pl. v, fig. 5.

Shell smooth or exhibiting faint growth-lines; whorls gently rounded, increasing rather rapidly; the umbilicus wide and open, each whorl embracing about half the previous one. Umbilical shoulders in the more adult shell are rounded and rather overhanging. The earlier whorls are much flatter than the later, which in very large specimens become much rounded.

Locality and horizon.—Bed *c*, Otamita (Hokonui Hills). The fragment illustrated occurred near the *Mytilus-problematicus* Bed, south of the Wairoa Gorge, Nelson. In the Geological Survey Collection is a magnificent specimen from Nugget Point, measuring 18 inches in diameter. Carnic. Large *Discophyllites* are recorded from New Caledonia.

Remarks.—*Discophyllites* is a sub-generic name proposed by Hyatt for a group of forms connecting *Monophyllites* and *Rhacophyllites*. The peculiarities of the suture are said to be that the siphonal lobe is deep and narrow, and divided by a high median prominence, and the siphonal saddle is diphyllic. Three species have been described: *D. patens* Mojsisovics, from Europe; *D. ebneri* Mojsisovics, from the Himalayas; and *D. insignis* Gemmellaro, from Sicily. Prof. Diener remarks that all three form a well-defined and closely-allied group ranging from Middle Carnic into Lower Noric strata. The New Zealand form seems to agree closely with the Himalayan *D. ebneri*.

Aulacoceras sp. (Pl. XVII, figs. 4 & 5.)

1878. *Belemnites otapiriensis* Hector, Trans. N.Z. Inst. vol. x, p. 485.

In one example the end of the guard and the anterior part of the phragmocone are both missing. The guard is soft and friable, and there are one or more longitudinal grooves on it. The phragmocone is nearly twice as long as the guard, and has eleven or twelve air-chambers remaining. The septa are irregularly spaced, and the siphuncle is marginal. A label attached to this specimen (which is figured in Pl. XVII, fig. 4) states that it is the holotype of Hector's *Belemnites otapiriensis*. A highly-idealized illustration of this specimen, which Hector caused to be printed, has recently been issued.[1] It is 150 mm. long.

Another specimen consists of a fragment of a guard in very hard greywacke, which, when dissolved out with acid, yielded a gutta-percha squeeze (illustrated in Pl. XVII, fig. 5). About half the surface is seen, and has three longitudinal ribs separated by two, sharp and deep furrows. The surface of the ribs is gently rounded,

[1] Bibliography, 47, pl. v, fig. 1.

and one of them bears five longitudinal parallel cuts. A very sharp and faint rib passes down the bottom of each of the furrows.

Locality and horizon.—Hector's specimen comes from Oreti railway-cutting (Hokonui Hills), and is probably Noric; the fragment of guard is from the *Spiriferina* Beds at Eighty-Eight Valley, Nelson, and is probably Carnic. Both specimens belong to the New Zealand Geological Survey Collection.

Remarks.—The first specimen is contained in a large piece of decomposed felspathic sandstone, and seems to be specifically indeterminable. The fragment of guard agrees well with a similar fragment of *Aulacoceras sulcatum* Hauer, illustrated by Mojsisovics.[1]

The New Zealand Geological Survey possesses fragments of phragmocones of belemnites of the *Atractites* group which are of large size; but most of them seem to be from Jurassic deposits.

GASTEROPODA.

PATELLA (?) NELSONENSIS, sp. nov. (Pl. XVIII, figs. 8 *a* & 8 *b*.)

Shell patelliform, the apex directed forwards and situated about the anterior third portion of the shell. The shape is not always symmetrical: in one example the apex is slightly inclined to the left, and in another the left anterior position of the shell slopes more steeply than the rest of the surface. The decoration consists of fine rounded ribs, which radiate from just below the apex to the margin. Between the primary ribs three or four smaller ones commence at various distances below the apex, but do not attain the strength of the primary ribs. The ribs are crossed by a regular series of faint, close-set, concentric growth-lines, giving the surface a latticed appearance. The shell is fairly thick, and the muscle-scar in the interior is broad, but not very distinct, and in one specimen seems to continue round the inside of the shell, while in another it appears to be interrupted on the left anterior side. The largest specimen that I examined was 71 mm. long, 65 mm. wide, and 36 mm. high.

Locality and horizon.—It has only been found in the Kaihiku Beds at Eighty-Eight Valley (Nelson district). Ladino-Carnic.

The New Zealand Geological Survey possesses several large examples, of which, except in one instance, the interior casts alone have been preserved. From this one I made a gutta-percha impression showing the outer surface, which I have taken as the holotype. It has a small mass (apparently of stromatoporoid coral) attached to its outer side.

Remarks.—It is possible that this shell may be a Capulid or perhaps a *Siphonaria*, in which case the apex would be posteriorly directed. The apparent interruption of the muscle-scar on one side rather suggests the latter genus as being the correct one.

[1] Bibliography, 32, pl. xiii, fig. 4.

Pleurotomaria (Sisenna) hectori, sp. nov. (Pl. XVIII, figs. 5 *a*–5 *c*.)

Shell consisting of about seven whorls; the spire is depressed; the upper surface of the first three whorls is nearly flat, but in the later whorls it is rather concave and slopes towards the line of nodes. The slit-band occurs about two-thirds of the distance above the base of the body-whorl and nearly half the distance above the suture of the penultimate whorl. The earliest whorls seem to be smooth. A row of heavy rounded nodes occurs both above and below the slit-band; those below it project beyond the slit-band, and form the keel of the shell. The nodes above and below the slit-band are of about equal size, are rather irregularly spaced, and occasionally tend to coalesce one with the other. The slit-band has a faint furrow above and below it, and between it and the nodes. Below the keel the surface of the shell is slightly concave; it then becomes convex, and then again concave towards the umbilicus, which is partly covered and obscured by a thin callosity of the inner lip. Below the keel the growth-lines bend sharply backwards, and then curve forwards again and pass to the umbilicus. This forward curving produces a tongue-like projection of the lip below the notch. The notch of the lip is about 10 mm. deep, the diameter of the shell is 34 mm., its height 20 mm., and the height of the spire 15 mm.

Locality and horizon.—Bed *c*, Otamita (Hokonui Hills). Carnic. I collected two or three very fine specimens here. I also found casts of it in the Carnic beds in the river-section of the Wairoa Gorge, and a cast of this (or of a very similar shell) in the Noric beds, with *Pseudomonotis ochotica*, at Garden Gully, in the Nelson district.

Remarks.—This shell may be placed in Koken's Pleurotomarid group *Sisenna*, which includes several Upper Triassic forms having a depressed spire, step-like whorls, and the slit-band situated between two ridges on the upper and outer side of the whorl. The tongue-like projection of the lip below the notch is also characteristic of this group. Koken says, however, that in *Sisenna* the umbilicus is open, whereas in the form here described it is partly or completely covered. It bears a rather remote resemblance to a shell from the Upper Trias of Bear Island in the Arctic Ocean, called by J. Bœhm *Sisenna conwentzi*,[1] in which the umbilicus is also, as in the present shell, covered by a thin labial callosity.

Pleurotomaria hokonuiensis, sp. nov. (Pl. XVIII, figs. 6 *a*–6 *c*.)

Shell small, consisting of seven whorls increasing rather rapidly. The apex is pointed, and the earliest whorls are angular. About the fourth whorl a row of vertically-elongate nodes appears below the suture, together with five or six spiral thread-like lines, one of which crosses the centre of the line of nodes. The ornamentation

[1] Bibliography, 8, p. 51 & pl. vi, figs. 1, 9, 10, 16

almost disappears on the last whorl of some specimens, which in consequence become nearly smooth above the slit-band. The latter is rather broad, and occurs above the keel in the last whorl. The keel is decorated with a line of blunt nodes, and there are a number of parallel threads between it and the slit-band. Beneath the keel are about eight concentric spiral lines, which are crossed by the growth-lines. The umbilicus is covered by a callosity of the inner lip. The slit-band seems to correspond to a rather deep notch in the lip. Diameter=18 mm.; height=10 mm.

Locality and horizon.—Bed *c*, Otamita (Hokonui Hills), where it is common. Also on Mount Heslington, Nelson. Carnic.

Trochus (Tectus) marshalli, sp. nov. (Pl. XVIII, fig. 7.)

Shell trochiform, consisting of eight whorls, which are sharply keeled, and each one slightly overhangs the suture below it. The whorls are slightly concave above the keel. Below the keel the base is hollowed out and concave. The keel is decorated with a line of forward-pointing nodes, which rather resemble the teeth of a saw. The lower part of each whorl above the keel is decorated with five or six parallel thread-lines, and beneath it are several still fainter lines.

The columella is strong and twisted, and folded near the inner lip. The aperture was not preserved. Diameter=15 mm.; height =18 mm.

Locality and horizon.—Bed *c*, Otamita (Hokonui Hills), where Prof. Marshall collected it during one of our visits. Carnic.

Remarks.—Several species of Trochoid shells with a twisted inner lip occur in the Alpine Hallstatt Limestone, and are figured by Koken under the generic name *Tectus*; but none of them resemble the form here described. It may seriously be questioned whether these Mesozoic Trochoids are congeneric with the Tertiary and recent genus *Tectus*.

Coronaria spectabilis, sp. nov. (Pl. XVIII, fig. 4.)

The shell consists of fifteen or more whorls which increase slowly in size; the test is fairly thick, the nodes being but faintly visible on the internal cast. The decoration consists of a series of prominent rounded nodes of elongate outline, arranged with their longer axes upright. The nodes occupy most of the surface of each whorl, but above them, and just below the suture, is a flat band which bears three or four raised spiral lines with shallow grooves between them. A series of fainter raised spiral lines passes round that part of the whorl which is occupied by the nodes, and across the depressions between them. The umbilicus seems to have been shallow; but the shape of the aperture or lip could not be ascertained. The earliest whorls appear to have been devoid of ornamentation. The holotype is 96 mm. long, and has an apical angle of 14°.

Locality and horizon.—Western slopes of Mount Heslington,

south of the Wairoa Gorge (Nelson), where fragments, often of large specimens, are not rare. It is also found at Nugget Point. Carnic.

The holotype is a mould belonging to the Geological Survey Collection, and comes from Mount Heslington. After preparing it, I was able to make a gutta-percha squeeze (fig. 4). The Survey also possesses a poorly-preserved fragment, consisting of several whorls, of a specimen from Nugget Point, which must have measured nearly a foot in length. I have several fragments from Mount Heslington.

Remarks.—This handsome shell seems to agree generically with Koken's genus *Coronaria*, of which several species occur in the Hallstatt Limestone. The genus resembles in some ways the *Zygopleura* group of the Loxonematidæ.

Bourguetia (?) arata, sp. nov. (Pl. XVIII, fig. 3.)

This shell consists of six or seven whorls, which increase rather rapidly in size; the body-whorl is large and rounded, and occupies rather more than half the length of the shell. The sutures are rather deep, and the whorls form a narrow platform below them. The decoration consists of spiral, rounded, parallel, raised, equidistant ridges, between which are furrows of about the same width as the ridges. There are about fifteen ridges on the body-whorl. A shallow umbilicus seems to be present, but the shape of the aperture could not be seen. Height=32 mm.; width of body-whorl=24 mm.

Locality and horizon.—Mount Heslington (Nelson). The holotype from which I made a gutta-percha impression belongs, together with several fragments from the same locality, to the Geological Survey Collection. I found a cast of a smaller specimen, 20 mm. high, in hard greywacke at Nugget Point. Carnic.

Remarks.—Owing to the poor state of preservation of the material, the generic position of this shell cannot be determined with certainty, and its attribution to *Bourguetia* is somewhat conjectural.

Dentalium sp. (Pl. XVIII, fig. 2.)

Length=originally about 37 mm. Greatest breadth=7 mm. at the anterior end; the posterior end is missing. The shell is gently curved: it is oval in section at the anterior, and nearly circular towards the posterior, end. The shell is rather thick, smooth, and ivory-like, with fine concentric growth-lines. The edge of the aperture is sharp and oblique, the margin being high and convex on the concave side, and concave on the ventral or convex side of the shell. The surface towards the aperture is rounded on the concave, flatter on the convex side. The growth-lines correspond to the obliquity of the aperture.

Locality and horizon.—Bed *c*, Otamita (Hokonui Hills). Carnic.

Conularia sp. (Pl. XVIII, fig. 1.)

Length=originally about 27 mm.; width at the aperture=9 mm. The section seems to be more or less square or rectangular. In most of its features this *Conularia* resembles *C. lævigata* Morris from the Permo-Carboniferous of Australia, which also occurs in beds of similar age in the Salt Range. In the fineness of its striæ it recalls also *C. tenuistriata* McCoy.

Locality and horizon.—Bed *e*, Otamita (Hokonui Hills); also in the *Mytilus-problematicus* Bed at Eighty-Eight Valley, near Nelson, and in the *Pseudomonotis-richmondiana* Bed on the south side of the Hokonui Hills. Carnic and Noric. It seems to be widely distributed, but is scarce and, as a rule, poorly preserved.

LAMELLIBRANCHIATA.

The New Zealand Triassic Lamellibranchs are of considerable interest. An edentulous shell with a general resemblance to *Cardiomorpha* I place, for want of contrary evidence, among the Palæoconchs. Taxodonts are represented by *Palæoneilo*, *Leda*, and *Macrodon*. Forms of great zonal value occur among the Anisomyarians, of which *Daonella indica* fixes the Ladino-Carnic horizon, several forms of *Halobia* the Carnic, while great masses of *Pseudomonotis* indicate the Noric horizon. The Alpine form, *Monotis salinaria*, also seems to occur; but the exact horizon which it occupies in New Zealand is not yet determined. *Mytilus* (?) *problematicus* is an important fossil in the Carnic beds, hitherto found only in the South Island, but it recurs in New Caledonia. Forms of *Cassianella*, *Pinna*, *Pecten*, *Limatula*, etc., also occur. A series of curious and very variable more or less *Lima*-like Myalinidæ is common in the Carnic. These forms show affinities with *Pergamidia*, *Mysidia*, and *Mysidioptera* of the Upper Trias of Asia Minor and the Alps, and I have applied to them the new generic name *Hokonuia*.

The Schizodonts include *Megalodon* and several species of *Myophoria*, one of which has hitherto been mistaken by New Zealand geologists for a *Trigonia*. The genus *Anodontophora*, of which at least three species occur, seems to be a Schizodont, the dentition of which has become obscure or obsolete. The Eulamellibranchiata are represented by *Palæocardita*, *Pleurophorus*, and possibly *Anisocardia*.

Cardiomorpha (?) nuggetensis, sp. nov. (Pl. XXI, fig. 7.)

Shell thin and platy in structure. Valves apparently equal in size, edentulous; beaks very anterior, pointed, close together, and incurved. Hinge-area long and slightly arched. Beneath the beaks there is a sunken false lunular depression. The valves are closed all round, except in the depression below the beak, where they gape to a slight extent for a short distance, apparently in order to allow the passage of a byssus. The surface is decorated with broad

irregular growth-ripples, especially towards the beaks, but is otherwise smooth. Anterior margin nearly straight, lower margin gently rounded, and hinder margin below the hinge-line rounded.

An adult shell is 49 mm. long, 36 mm. high, and the two valves are 24 mm. thick.

A young specimen is shorter relatively to the height than the adult, measuring 18 mm. in length and 15 mm. in height.

Locality and horizon.—Nugget Point, in a loose block washed out of Carnic beds in the cliff-section. I collected four or five specimens.

Remarks.—It is with considerable reserve that I refer this edentulous shell to the Palæoconch genus *Cardiomorpha*. The shape of the young shell, however, suggests this genus. The gape below the beak apparently precludes it from belonging to the group of *Anodontophora*; while the laminar structure of the shell and the byssal gape suggest that it may be a Myalinid.

PALÆONEILO OTAMITENSIS, sp. nov. (Pl. XXI, fig. 21.)

The shell is rather thick; anteriorly the valves are somewhat strongly inflated, but they tend to flatten out posteriorly. The beaks are rather prominent, anteriorly situated, and directed forwards. The margin is well rounded in front, gently curved below, and is produced, narrowing gradually behind. There is no trace of a posterior ridge on the shell, the surface of which is gently rounded and smooth. The concentric growth-lines are fine, evenly spaced, and very regular. When the hinge-line is scraped away, a row of many teeth is seen behind the beak, with about six much larger teeth in front of it. Length=17 mm.; height=9 mm.; depth of right valve=3 mm.

Locality and horizon.—Bed *c*, Otamita. Carnic. I collected several specimens with the shell on them.

Remarks.—The comparatively-smooth surface of this shell suggests that of *P. elliptica* Goldfuss, from St. Cassian; but the beaks are more anterior, and the shell more inflated beneath them.

PALÆONEILO cf. PRÆACUTA Klipstein. (Pl. XXI, fig. 22.)

1895. A. Bittner, 'Lamellibranchiaten der Alpinen Trias' p. 143 & pl. xvi, figs. 32–35.

The shell is fairly thick, the beaks situated well forward. The anterior margin is well rounded, the lower margin gently curved; the posterior portion of the shell is produced, and tapers rather rapidly. The anterior portion of the valves is considerably inflated, but they flatten out posteriorly. An appreciable blunt ridge passes from behind the beaks to the lower posterior margin. The concentric growth-ridges are well marked and fairly regular; a few of the furrows between them are wider than the rest. Length=18 mm.; height=10 mm.

Locality and horizon.—Bed *c*, Otamita (Hokonui Hills). Carnic. I collected two or three fine specimens with the shell on them.

Remarks.—This form agrees fairly well with *P. præacuta* from St. Cassian, but differs in having the beaks rather more anterior. It comes nearest to Bittner's fig. 34, yet the differences hardly seem to warrant a new specific name for it.

Leda semicrenulata, sp. nov. (Pl. XXI, fig. 20.)

Shell rather thick; beaks broad and low, situated about the middle of the shell, and directed slightly backwards. The anterior margin is well rounded, the outline forming almost a semicircle; the lower posterior margin of the shell is produced upwards, and the hinder part is rostrate. The decoration consists of about forty-five rather sharp concentric ridges which are fairly regular on the anterior portion; but near the beaks and on the posterior half, though remaining constant in width, they become curiously wavy and broken, producing a crenulated appearance. A blunt ridge passes from the beaks to the lower end of the rostrate hinder margin. Length=18 mm.; height=13 mm.

Locality and horizon.—Bed *c*, Otamita (Hokonui Hills). I collected two or three specimens with the shell on, but all rather crushed.

Macrodon cf. curionii Bittner. (Pl. XXI, figs. 12 & 13.)

1895. 'Lamellibranchiaten der Alpinen Trias' p. 121 & pl. xv, fig. 16.

Shell fairly thick. The hinge-margin is straight, and is produced in front of the beak, terminating rather sharply where it joins the gently-curved and retreating anterior margin. About the middle of the lower margin, which is nearly straight, the shell is contracted by a shallow sulcation extending almost to the beak. The concentric growth-lines are well marked, but irregular. Behind the beaks there is a faint trace of radial ribs interrupted by the growth-lines. Length=about 33 mm.; height=13 mm.

Locality and horizon.—Bed *c*, Otamita (Hokonui Hills). I collected a left valve there with the shell preserved, but damaged at both ends. The New Zealand Geological Survey possesses the internal casts of two specimens from Mount Heslington (Nelson), showing the characteristic dentition; but they are not specifically determinable, though probably belonging to the same species. Carnic.

Remarks.—At least one species of *Macrodon* occurs in the New Zealand Trias, but the shells are scarce. My specimen resembles rather closely the above-named species from the Raibl Beds of Lake Iseo (Lombardy). It recalls also a closely-related form, *M. esinensis* Stoppani, from the Esino Limestone, which Bittner figures on the same plate, figs. 17 & 18.

Pseudomonotis and Monotis.

The *Monotis*-like shells, which Hochstetter brought from Richmond, near Nelson, were identified by Zittel as a variety of *Monotis salinaria* and called var. *richmondiana*. The fact that

they possess an anterior byssal notch in the right valve, which is wanting in the true *M. salinaria*, was pointed out by Teller,[1] who consequently placed them in the genus *Pseudomonotis*.

I have found this byssal ear and notch in all the New Zealand specimens that I examined, except in those that occur in limestone at Okuku. In some cases the rock must be carefully cut away to show it; but it is always present, except in the case just mentioned. In the large flat varieties of *Pseudomonotis ochotica* the ear and notch are reduced to the smallest possible size.

F. Frech[2] thinks that the three circum-Pacific species of *Pseudomonotis*: namely, *Ps. ochotica*, *Ps. richmondiana*, and *Ps. subcircularis*, are varieties of one and the same shell. He believes that *Ps. richmondiana* occurs in two forms, and figures and describes a new form as var. *truncata*, pointing out its resemblance to *Ps. ochotica* var. *sparsicostata*. He also considers *Ps. subcircularis* identical with *Ps. ochotica* var. *sparsicostata*.

Ps. richmondiana has been recorded only from New Zealand and New Caledonia. *Ps. subcircularis* is a British Columbian, Californian, and South American Cordilleran form, and characterizes the Noric Beds. *Ps. ochotica* was first discovered at Verkhoyansk in Arctic Siberia, in beds of Noric age. It was found later in Japan,[3] where it occurs in beds very near the top of the Trias and a very short distance below the overlying Jurassic. It is also recorded from Central Timor, where a specimen of *Ps. ochotica* var. *densistriata* was found in a pebble in the Talau River.[4]

I now record *Ps. ochotica*, as defined by Teller, for the first time in New Zealand. It is a very variable species, but an even greater range of varieties is present among my specimens than among those from Arctic Siberia figured by Teller and Mojsisovics.

Near the head of Garden Gully, on its western slope a mile south-west of the Wairoa Gorge, in the Nelson area, I was fortunate in finding a bed of fine-grained dark greywacke-mudstone, containing a large series of forms which undoubtedly belong to the Asiatic fossil *Ps. ochotica*. The beds seem to occupy the middle limb of a syncline, or possibly a faulted syncline of the Trias, and are, I think, the highest Triassic rocks exposed in the Nelson district. In this district the varieties of *Ps. ochotica* occur in the bed in Garden Gully to the exclusion of *Ps. richmondiana*. The typical *Ps. richmondiana* occurs in vast numbers in a bed exposed some distance away on the opposite slope of the valley to the east; but the two forms are clearly separated, and I have little doubt that *Ps. richmondiana* occurs at a lower horizon than *Ps. ochotica*.

The felspathic sandstone at Richmond, 5 miles north-east of

[1] Bibliography, 35, p. 104. It is clear that the genus *Pseudomonotis* does not represent a natural group. The *Pseudomonotis* forms of the Upper Trias are much more closely related to *Monotis salinaria* than they are to shells called *Pseudomonotis* in the Permian or Jurassic, such as *Ps. speluncaria* or *Ps. echinata*.

[2] Bibliography, 13, pl. lxviii.

[3] Bibliography, 33, p. 175.

[4] Bibliography, 49, p. 189.

Garden Gully, contains only *Pseudomonotis richmondiana*. Near Albatross Point, in the Kawhia district, the dark shales underlying the Rhætic Series, close to an igneous intrusion, contain the large flat *Ps. ochotica* var. *densistriata* and a form approaching var. *pachypleura*, while *Ps. richmondiana* seems to be absent, a fact which further goes to indicate the higher position of the *Ps.-ochotica* horizon. I have seen no *Ps. ochotica* from the Hokonui Hills, but *Ps. richmondiana* occurs at various places in that district. Okuku is the only locality in New Zealand where the *Monotis*-like shells form a limestone. Though it seemed unlikely to me that the Alpine *Monotis salinaria* should occur in New Zealand, yet it is not an impossible contingency. Wanner,[1] who paid great attention to the differences between this shell and the large flat forms of *Ps. ochotica*, records its occurrence in the island of Serang.

I have already stated, in discussing the Okuku locality, that I am compelled to regard the shell which occurs there as belonging to the Alpine form *Monotis salinaria*.

PSEUDOMONOTIS OCHOTICA Teller. (Pl. XIX, figs. 1–8.)

1886. E. von Mojsisovics, 'Arktische Triasfaunen' p. 116 & pl. xvii, figs. 1–15, pl. xviii, figs. 1–11.
1907. J. Wanner, 'Triaspetrefakten der Molukken' p. 189 & pl. viii, fig. 9.

This is a very variable species, and Mojsisovics and Teller have carefully described and illustrated from the original locality at Verkhoyansk in Arctic Siberia five varieties, in addition to the form which they regard as the normal type. These they have called vars. *densistriata*, *eurhachis*, *ambigua*, *pachypleura*, and *sparsicostata*.

In the one bed at Garden Gully, near the Wairoa Gorge, I collected specimens more or less closely comparable with all these varieties, and, in addition, a form still more strongly arched and ribbed than any that are recorded from the original locality, which I have ventured to institute as a new variety under the name *acutecostata*. All the varieties occur indiscriminately mingled together in one and the same rock.

It is not necessary here to recapitulate the description of the different varieties as given by Teller; but I may say that the large flat *Salinaria*-like variety *densistriata* (fig. 1) occurs in very characteristic form, and that some of the specimens approach the North American form *Pseudomonotis subcircularis* in the expansion and rounded outline of the anterior margin.

The posteriorly elongate and expanded, coarsely-ribbed variety *pachypleura* (fig. 3) occurs together with a form presenting a more or less quadrilateral margin, which Teller calls var. *eurhachis* (fig. 5). The variety *sparsicostata*, approaching in character the large and nodosely-ribbed form of *Ps. richmondiana*, which

[1] Bibliography, 49, p. 190.

Frech calls var. *truncata*, can also be identified among the New Zealand shells (fig. 4).

A small, dwarfed, and strongly-ribbed form, in which the right valve is often strongly arched and bent downwards towards the margin, very similar to the variety that Teller calls *ambigua* (fig. 2), also occurs in association with all the other varieties.

It may here be emphasized that I regard these different forms as representing individual variants in one very variable species, since some confusion or misuse of terms may arise in calling them varieties. However, in describing the following form as var. *acutecostata* nov., I am merely following the plan adopted by Mojsisovics and Teller, who describe the specimens of different shape from Verkhoyansk and Japan as varieties.

Var. ACUTECOSTATA, nov. (Pl. XIX, fig. 7.)

The left valve is strongly arched, the beak is pointed, tapers rapidly, and is acutely bent over the hinge-area. The outline of the shell is angular, and there are about fourteen primary ribs, some of them very acute and prominent, others lower and more rounded. Other very much smaller secondary ribs appear about halfway between the beak and the margin.

Locality and horizon.—Garden Gully, south of the Wairoa Gorge (Nelson), on the western slope of the valley, where all the varieties occur. On the coast, south of Kawhia, towards Albatross Point, where the varieties *densistriata* and *pachypleura* occur. Upper Noric.

I collected a large series of examples at Garden Gully and several at Kawhia. The Geological Survey possesses several specimens of the different varieties from the Nelson district, but the exact bed whence they came is not identified.

Remarks.—The geographical distribution of this form has already been discussed. It has not yet been recorded from New Caledonia.

PSEUDOMONOTIS RICHMONDIANA Zittel. (Pl. XIX, figs. 9*a* & 9*b*.)

1864. 'Paläontologie von Neu-Seeland' p. 26 & pl. vi, figs. 1 *a*–1 *e*.

This species has an oval and gently rounded outline, and the margin is never angular as it is in some of the forms of *Ps. ochotica*, nor does the shell show the extremes of variation exhibited by the individuals of that species. The byssal notch and ear in the right valve are small, but well developed; the left valve is gently arched and rounded, the right nearly flat. The ribs are regular on both valves, being straight or slightly curved. Fainter secondary ribs occur between the primary ribs, and commence a short distance from the beak. There are about twenty-eight ribs on the left valve.

Frech[1] describes a form under the name var. *truncata*, and

[1] Bibliography, 13, p. 506 & pl. lxviii, figs. 4 *c*–4 *d*.

remarks that it approaches very closely to *Pseudomonotis ochotica* var. *sparsicostata*. I have a mass of felspathic sandstone from Richmond, with a specimen on it which seems to agree with Frech's variety. It certainly resembles the variety of *Ps. ochotica*, but it seems to me to be merely a more fully-grown example of *Ps. richmondiana*, in which the ribs have become nodose towards the margins, where they are interrupted by coarse growth-lines. It retains, however, the characteristic rounded outline of this species: it measures 81 mm. in length and 65 mm. in height.

The more common form, however, is smaller. The Geological Survey possesses a very fine specimen with the two valves together, which is illustrated (figs. 9*a* & 9*b*). It is 45 mm. long, 37 mm. high. and 11 mm. thick, and comes from the eastern slopes of Mount Heslington, near Garden Gully.

Locality and horizon.—Richmond, and the eastern slope of Garden Gully in the Nelson district; also in the Hokonui Hills. It is wanting in the coast-section at Nugget Point. It occurs in enormous quantities in more or less decomposed felspathic sandstone, and marks a Noric horizon apparently below that of *Ps. ochotica*. In only one case did I see any other fossil associated with it, whereas I found several gasteropods and brachiopods in the *Pseudomonotis-ochotica* Bed in Garden Gully. It is recorded from New Caledonia.

MONOTIS SALINARIA Bronn. (Pl. XIX, fig. 10, & Pl. XX, figs. 1–3.)

1830. Leonhard & Bronn, Jahrb. f. Min. &c. p. 284 & pl. iv, fig. 1.
1907. J. Wanner, 'Triaspetrefakten der Molukken' p. 190 & pl. ix, figs. 2–4.

Among the *Monotis*-like shells that occur at Okuku the right valves are nearly as convex as the left, whereas in most specimens of *Pseudomonotis* in New Zealand the right valve is nearly flat or even slightly concave. Also, as already stated, no trace can be seen of the anterior byssal notch and ear which occur in the right valve of *Pseudomonotis*.

For some unapparent reason the shells in this limestone-bed tend to vary in a manner analogous, though to a less extreme degree, to the variation in those of *Pseudomonotis ochotica*. The word 'variety,' therefore, is to be understood in the same sense as that in which I have used it in discussing the last-named species.

The variation tends to produce a reduction in size from the large flat form which may be regarded as the normal form, accompanied by a progressively strong arching of the valves, especially of the left valve, without, however, any increase in the size of the ribs.

MONOTIS SALINARIA. (Pl. XIX, fig. 10.)

The largest specimen that I examined is a left valve 70 mm. long and 57 mm. high. It has twenty very regular, equidistant, straight, or slightly-curved primary ribs, which radiate from the beak; between these occasional fainter secondary ribs appear at

various distances from the beak, and near the margin they attain almost the strength of the primary ribs. This form seems to resemble in every way the typical Alpine *Monotis salinaria*.

Var. INTERMEDIA, nov. (Pl. XX, fig. 1.)

This seems to be a fairly-constant variety: the left valve is rather strongly arched, and has sixteen narrow and very regular primary ribs, between each of which in one specimen that I examined fainter secondary ribs occur at various distances from the beak. In another left valve the primary ribs are rather broader, and become nodose towards the lower margin, owing to interruption by the growth-lines; and very faint, in some cases scarcely perceptible, secondary ribs occur between the primary ribs, commencing about halfway between the beak and the lower margin. Length=46 mm.; height=37 mm.; depth of left valve=14 mm.

Var. HEMISPHERICA, nov. (Pl. XX, figs. 2 & 3.)

Shell small, the left valve very strongly arched and rounded; the beak is inflated, and projects beyond the hinge-line, which is very short. The margin is rounded and contracted in front, but rather produced behind. There are about seventeen regular, low, rounded primary ribs, more or less equal in size, between which an occasional very faint secondary rib occurs towards the lower margin. A right valve is rather strongly arched, but much less so than the left; the beak is pointed and not inflated; and the hinge-line is short, with a faint posterior wing. There are about fifteen primary ribs, more or less equal in size, but rather irregularly spaced; and in the two widest spaces about the middle of the shell a very faint secondary rib occurs. A left valve is 22 mm. long, 22 mm. high, and 12 mm. deep. A right valve is 23 mm. long, 19 mm. high, and 9 mm. deep.

Locality and horizon.—Okuku (Ashley County), in the Canterbury Alps, in limestone. Horizon uncertain, Carnic or Noric. All the specimens that I examined belong to the New Zealand Geological Survey, and were collected by Mr. McKay in 1879.

Remarks.—*Monotis salinaria* is generally a Noric fossil, but occurs in Europe also in Carnic beds. It ranges from the Alps and Sicily through Afghanistan, Baluchistan, the Pamirs, Himalayas, and Borneo to the Moluccan Islands, and is now recorded for the first time from New Zealand as distinct from the genus *Pseudomonotis*.

DAONELLA INDICA Bittner. (Pl. XX, fig. 7, & Pl. XXI, fig. 5.)

1899. 'Trias Brachiopoda & Lamellibranchiata' Pal. Ind. ser. 15, vol. iii, pt. 2, p. 39 & pl. vii, figs. 4–11.

1907. J. Wanner, 'Triaspetrefakten der Molukken' p. 202 & pl. ix, figs. 8–9, pl. x, figs. 2–3.

The outline is rounded so far as one can ascertain, since most of the specimens are broken prior to fossilization. The hinge-margin is straight: the beak projects slightly above it, and is situated about

the middle of the hinge-margin. There is no anterior ear as in *Halobia*, and consequently there can be no doubt that this shell belongs to the genus *Daonella*. The ribs commence near the beak, only a small area of which is free from them, and sweep regularly down to the margins. Secondary furrows commence some distance from the beak, but do not reach the depth of the primary furrows, and it is only occasionally that a rib is divided by two furrows. Concentric ripples are confined to the umbonal regions, and growth-lines are scarcely seen. There is a very narrow triangular space extending along the posterior hinge-margin, which is free of ribs. It attains a considerable size: a fragment of a large specimen in my collection (Pl. XX, fig. 7) shows that it must have been about 70 mm. long and 60 mm. high.

Locality and horizon.—In New Zealand this form is confined to the Kaihiku Beds, and affords very strong evidence that these are of Ladinic or Lower Carnic age. It seems to occur in all the localities where the Kaihiku Beds are found. I collected several specimens in the Caroline Cutting on the south side of the Hokonui Hills, and on looking over the Geological Survey Collection I identified many specimens from the Nelson district, Mount Potts, and other localities.

Remarks.—This is the only member of the *Daonella*[1] and *Halobia* group that occurs in the Kaihiku Beds, and seems to be in every way identical with the Himalayan form. It belongs to the group of *D. tyrolensis* of the classification of Mojsisovics, from which it differs in details well defined by Bittner. It resembles also in some ways *D. sakawana* Mojsisovics, a Japanese fossil. It is widely distributed in the Himalayan Trias, and in the Shal-Shal section and other localities, occurs in a bed which Diener took to be the top of the Muschelkalk complex, but later attributed to the *Aonoides* Beds. Wanner[2] records it, figuring specimens from the southern coast of Timor, and regards it as marking the base of the Upper Trias. This form has not been recorded from New Caledonia. In the Spiti district of the Himalayas[3] it is associated with *D. lommeli*, a well-known Alpine Ladinic fossil.

HALOBIA ZITTELI Lindström, var. ZEALANDICA, nov. (Pl. XX, fig. 6, & Pl. XXI, figs. 1–2.)

Beak rather prominent, somewhat inflated, directed forwards, and situated rather in front of the middle of the straight hinge-line. The anterior ear is broad and well marked, triangular in outline; it widens out rapidly, and is strongly arched and rounded. This ear is marked off from the rest of the shell by a broad shallow sulcus. The radial ribs begin just below the beak as a series of closely-set,

[1] The fossils which Zittel identified as *Halobia lommeli* were later described by Mojsisovics as *Halobia hochstetteri*. *H. lommeli* is really a *Daonella*. The true *D. lommeli*, a Ladinic fossil, does not seem to occur in New Zealand, the Kaihiku horizon being apparently too high for it.

[2] Bibliography, 49, p. 202. [3] Bibliography, 10, p. 11 & pp. 143–45.

very faint, raised, rounded lines, which are produced regularly downwards and backwards with a slight anteriorly-concave bend. Some distance below the beak they widen out, become wavy, and bend suddenly forwards, continue thus for a short distance and then bend downwards again less abruptly, passing towards the lower and anterior margins. In some specimens the hinder portion of the shell is almost smooth, in others the ribs continue in fairly-straight though wavy lines, between which a series of shallow furrows of very irregular width are produced. On the anterior ear the faint radial ribs are sometimes seen on the portion bordering the hinge-line. Concentric growth-ripples are well marked in the region of the beak, but are broad, shallow, and irregular in width. They are also developed on the anterior ear, but to a less extent. Secondary ribs appear intercalated between the primary ribs on the posterior portion of fully-grown shells. The marginal outline is difficult to construct, as the shells are nearly always imperfect; but the anterior ear projects beyond the lower anterior margin and is well rounded, and the margin retreats below it, at least in the right valve. Under the ear the margin is well rounded, the lower margin seems fairly straight or gently rounded, and the posterior margin broadly rounded.

This species attains a large size; the biggest example that I collected, when perfect, must have measured about 65 mm. in length and 42 mm. in height.

Locality and horizon.—Large specimens are rather common in brown, decomposed, fine-grained greywackes on the crest and saddle of Mount Heslington, south of the Wairoa Gorge, Nelson. It occurs also in Bed *e* in the Otamita section, Hokonui Hills, and I found some small examples in hard greywackes at Nugget Point, above the *Mytilus-problematicus* Bed. I collected specimens in various stages of growth in all these localities. Carnic.

Remarks.—This large and variable *Halobia* falls into the group of *H. fallax* of the classification of Mojsisovics. The New Zealand form seems to partake of the characters both of *H. zitteli* Lindström and of *H. superba* Mojsisovics. The sudden forward bending of the ribs occurs nearer the beak than in *H. superba*, but somewhat farther away than in *H. zitteli*. The ribs are less numerous than in *H. superba*, but they become wavy in the anterior portion of the shell, which seems not to be the case in *H. zitteli*. However, the form here described seems to be nearer to *H. zitteli* than to *H. superba*, and I am inclined to regard it as a local variety of the former species.

H. zitteli comes from the Trias of Spitsbergen, where it occurs in rather high Carnic beds with *Pinacoceras* cf. *floridum*. It also occurs in the Upper Trias of Bear Island, and some forms figured as young examples from both these localities closely resemble some of the Halobias from New Zealand. *H. superba* occurs in the Carnic of the Austrian Alps.

Halobia hochstetteri Mojsisovics. (Pl. XXI, fig. 3.)

1874. 'Ueber die Triadischen Pelecypodengattungen *Daonella* & *Halobia*' p. 32 & pl. iii, figs. 7–9.

Hinge-line straight, the beak directed forwards, not very prominent, and situated rather in front of the median line. The anterior ear is triangular in shape and widens rapidly, is not inflated or rounded, and is marked off from the rest of the shell by a narrow and somewhat angular sulcus. The primary radial ribs begin below the beak, and consist of a series of rather broad flattened ribs of irregular width, separated by well-marked and rather deeply cut grooves. On these ribs two or three very much fainter secondary grooves occur some distance from the beak. At some distance below the beak (the distance seems to vary in different specimens), the ribs become wavy and bend very strongly forwards, continue thus for a short space, and then curve gently downwards again towards the lower and anterior margin. The hinder portion of the shell below the hinge-margin is devoid of ribs and almost smooth, and the ribs become very feeble towards the lower posterior margin in fully-grown shells. The anterior ear bears a shallow radial furrow not far below the hinge-margin.

Broad concentric growth-ripples occur on the young shell, but they are faint and rather irregular, and they tend to occur also on the anterior ear. Since specimens of any size are almost invariably broken, I cannot describe the marginal outline with any certainty, but it seems to have been similar to that of *H. zitteli* var. *zealandica*. This shell also attains a large size: for instance, a fragmentary specimen in my collection must have been 65 mm. long and 40 mm. high.

Locality and horizon.—Crest and saddle of Mount Heslington, Nelson. Bed *e*, Otamita, Hokonui Hills. It occurs in the same bed as the last-described form, and I collected several specimens of it.

Remarks.—Mojsisovics figures three specimens of *H. hochstetteri*, all of small size, which were apparently brought to Europe by Hochstetter and had been identified by Zittel as *Halobia lommeli*.[1] Mojsisovics gives a long and clear description of this form, of which the following are the main points:—

It is a rather high form, unstriated towards the hinder hinge-margin, with a wide anterior ear, on which beneath the margin a rather strongly-arched fold occurs, split at some distance from the beak by a sunken groove. Primary radial grooves are not numerous, and the ribs that they form are divided at varying distances, by further single or double grooves, into secondary ribs of dissimilar width. Near the forward and hinder part smaller ribs occur. Anteriorly the ribs reach to the ear. The ribs do not run straight, but undergo several bendings to and fro similarly, as is generally the case in the group of *H. fallax*. The wavy breaking of the ribs does not take place in all examples at the same age, and he remarks that it would be interesting to know whether this corresponds to any difference in geological age. Concentric ripples are very apparent on the upper half of the shell. Length = 13 mm.; height = 10 mm.

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[1] Bibliography, 51, p. 27 & pl. vi, figs. 2 *a*–2 *c*.

From the description it is clear that Mojsisovics only had shells in the young stage. Some of those that I obtained, and apparently identified correctly with *Halobia hochstetteri*, reach a much more adult stage, and show the sudden forward bending of the ribs.

He goes on to say that Lindström rightly considered this form to be distinct from *Daonella lommeli*, but erred in identifying it (though under reserve) with the Spitsbergen form *H. zitteli*, from which it is easily distinguished by its less numerous, wider, and more often wavy ribs. He compares it with *H. rugosa*, a form which attains a wide horizontal range in the European Alps. Bittner[1] regards *H. hochstetteri* as more closely related to *H. zitteli* than to *H. rugosa*, an opinion with which I thoroughly agree.

The specimens illustrated by Mojsisovics were said to come from the *Monotis-richmondiana* Beds at Richmond, near Nelson. By analogy with the Alpine and Spitsbergen Halobias he places this form high in the Carnic, in which case it should not occur with *Pseudomonotis richmondiana*, a Noric fossil. I never saw any Halobias in the *Pseudomonotis* Beds in New Zealand, and *Ps. richmondiana* generally occurs entirely by itself. I think, therefore, that the specimens that Hochstetter obtained must be from some other locality, possibly the Wairoa Gorge. Arthaber[2] attributes *Halobia hochstetteri* to a Noric horizon, probably because of its supposed occurrence in the same bed as *Pseudomonotis richmondiana*.

Halobia cf. austriaca Mojsisovics. (Pl. XXI, fig. 4.)

1874. 'Ueber die Triadischen Pelecypodengattungen *Daonella & Halobia*' p. 26 & pl. iv, figs. 12–13, pl. v, fig. 14.

The shell is about as long as it is high; the beak is slightly directed forwards; the ribs are not very numerous, flattened, irregular in width, and separated by rather sharply-cut furrows, some of which are deeper than others. The ribs are finer and more closely set on the posterior portion of the shell. Near the hinder hinge-margin a considerable portion of the shell is smooth. The primary ribs are split at various distances below the beak into two or four secondary ribs. The anterior ear is rather wide; it bears one or two faint radial ribs, and is not sharply differentiated from the rest of the shell. Concentric ripples are most prominent on the umbonal region, and pass across the anterior ear as well as over the rest of the shell. A specimen in my collection, which has the margins somewhat broken, measures about 26 mm. in length and 24 mm. in height.

Locality and horizon.—Bed *e*, Otamita, Hokonui Hills, where I collected three or four specimens, none of them very well preserved. Carnic.

Remarks.—This shell apparently belongs to the group of *Halobia rarestriata* of the classification of Mojsisovics; it comes

[1] Bibliography, 6, xlv, p. 254.
[2] Bibliography, 13, p. 241.

nearest to *H. austriaca*, which is a Carnic fossil and, in the Austrian Alps, builds up banks in the limestones with *Bucephalus subbullatus*. The flattened ribs of irregular width and the sharply-cut furrows of the present form recall those of the young shell of *H. hochstetteri*; but the beak in *H. austriaca* is less strongly inclined forwards, also the ribs show no waviness and do not bend forwards.

Halobia spp.

In addition to the three forms of *Halobia* already described, the Carnic beds of the New Zealand Trias contain at least two other smaller and less conspicuous forms, which appear to be distinctive and probably new species, although from the rather scanty nature of the material obtained by me I hardly feel inclined at present to record them as such. As they occur in the same bed at Otamita and Mount Heslington as the forms just described, and as they appear to be undescribed species, a description of them cannot add any further information regarding the horizon of these beds than that yielded by the forms which closely resemble *H. zitteli* and *H. austriaca*. I may remark, however, that a small *Halobia*, very common in Bed *c* at Otamita, strongly resembles a shell which Bittner illustrates under the appellation '*Halobia*, n. sp., aff. *neumayri* Bittner,' from the Upper Trias of Balia in Asia Minor. I do not recollect finding the forms allied to *H. zitteli* or *H. hochstetteri* in Bed *c* at Otamita, and so the small Halobias mentioned above may characterize a rather higher horizon. *Halobia neumayri*, which occurs at Balia, is a species of the group to which *H. zitteli* and *H. hochstetteri* belong. A careful and prolonged zonal collecting of the Carnic Halobias of the New Zealand Trias would probably yield further interesting results.

Mytilus (?) problematicus Zittel. (Pl. XX, fig. 8.)

1864. 'Paläontologie von Neu-Seeland' p. 28 & pl. viii, figs. *a*–*b*.

Shell thin, mytiliform, the beaks anteriorly situated, terminal, the upper posterior margin bluntly alate.

Area straight or slightly curved; behind the beak is a concave ligament-groove bearing faint parallel striæ. I saw no trace of hinge-teeth nor of muscle-scars. Some specimens seem to have a small, narrow, byssal sinus below the beak. There is a small plate or septum inside the beak. A typical specimen measures 109 mm. in length. The specimen illustrated is a small left valve.

Locality and horizon.—The *Mytilus-problematicus* Bed forms a very constant horizon about the middle of the Carnic in all the principal sections in the South Island. It has not been traced in the North Island, but reappears in New Caledonia. The bed is made up of incredible quantities of separated valves, among which an occasional valve of *Hokonuia*, or of the form next to be

described, occurs. The bed is specially well seen at Nugget Point, where it is about 10 feet thick.

Remarks.—The specific name that Zittel gave to this shell seems to imply some doubt as to its real affinities. I never found the two valves together, but the New Zealand Geological Survey Collection includes one or two examples in this condition, though not well enough preserved to show whether it is an exactly equivalve shell or not. This, as also the absence of muscle-scar impressions, makes a certain attribution impossible at present, but I strongly suspect that the form here described may be related to the Myalinidæ rather than to *Mytilus*.

MYTILUS (?) MIRABILIS, sp. nov. (Pl. XX, figs. 9 *a* & 9 *b*.)

Shell inflated, very strongly arched; the valves are nearly twice as deep as they are long, very much compressed antero-posteriorly. Beak small, anteriorly situated or terminal; area very short with a ligament-groove behind it, bearing faint parallel striæ. There is a small apical septum in the interior of the beak. In one specimen I detected a posterior muscle-scar of fair size, but saw no trace of an anterior scar. The hinge is edentulous.

Length=52 mm.; height=108 mm.; depth of valve=100 mm.

Locality and horizon.—It occurs rather commonly in the *Mytilus-problematicus* Bed at Eighty-Eight Valley, south of the Wairoa Gorge, Nelson. Carnic.

Remarks.—This shell has been called *Gryphæa* in New Zealand Geological Survey reports. The valves are always separated, but I have no doubt that it is an approximately or completely equivalve shell, as I collected both left and right valves. I feel sure also, after examining the shell-structure, which is of a laminar nature, that it is related to *Mytilus problematicus*, with which it occurs in intimate association and with which it seems to be connected by a series of intermediate forms that may be young specimens. It suggests, in fact, an enormously overgrown specimen of *Mytilus problematicus* in which the valves have become strongly arched. Fully-grown examples with the two valves together must have presented an extraordinary appearance, quite unlike that generally associated with *Mytilus*, a fact which causes me to question the generic attribution both of this and of *Mytilus problematicus*. The holotype is a right valve in my collection. The New Zealand Geological Survey possesses several specimens from Eighty-Eight Valley. This form generally occurs in a poor state of preservation, with the shell more or less completely dissolved away.

HOKONUIA, gen. nov. (Pl. XX, figs. 4–5 *b*; Pl. XXII, figs. 1–5.)

The shells belonging to this genus show very considerable diversity in size, shape, degree of inflation, thickness of shell, and situation of the beak. Some recall *Lima* in general shape, others *Myalina* or *Avicula*.

The shell-structure is more or less platy and foliaceous, recalling

in this respect that of the Australian Permo-Carboniferous genus *Eurydesma.* The hinge seems to be quite edentulous, and the articulation was so feeble that the two valves are always disconnected; but I have a few specimens in which the valves are only displaced slightly, and they obviously belonged together. From these it is evident that the valves were approximately equal in size and degree of inflation, although whether the valves were exactly equal or not is not clear. I am inclined to think that the left valve may have been slightly smaller than the right.

The hinge-line is straight or very slightly curved, and is less than the greatest width of the shell. Behind the beak in both valves is a longitudinal, concave, areal furrow, which extends for about two-thirds the length of the hinge-margin, and seems to have accommodated a partly sunken ligament. There is a small, blunt, thickened septum in the interior of the apex of each valve, recalling that in *Myalina* or *Dreissensia.* Behind the beaks is a flattened, obtusely-angular, posterior wing, which in some examples is but slightly differentiated from the hinder margin of the shell.

The anterior portion of the shell in front of, or below, the beak differs markedly in the right and left valves, and shows features which are common to all the species of the genus whatever may be their shape or degree of inflation.

The right valve immediately below the beak bears a strong curved or semicircular truncation, which is bounded on the posterior side by a rounded, raised or thickened ridge of shell. In front of this truncation, and just below the apex, is a rather long tongue-shaped projection (Pl. XXII, figs. 1, 2 *a*, & 2 *b*), and immediately below this is a conspicuous retreat of the shell-margin forming a deep and marked sinus. The upper edge of the anterior tongue-like shelly process carries a raised or thickened ridge.

In the left valve no concave truncation is seen in front of the beak as in the right valve; but below the beak the shell-margin is arched and thickened, and retreats so as to produce a narrow byssal opening similar to that of *Mytilus* or *Myalina* (Pl. XX, fig. 5 *b*).

The tongue-like process of the right valve projects beyond the plane of junction of the valves, and must have covered the upper part of the opening produced by the retreat of the margin of the opposing left valve. The opening which remained beneath the process when the two valves were together seems to have allowed the passage of a byssus.

In one example (Pl. XXII, fig. 2 *a*) a fairly-large posterior muscle-scar is observed rather more than halfway down the shell between the median line and the posterior margin; but I could see no trace of an anterior scar, and in nearly all the specimens the muscle-impressions are quite obscure. One cannot therefore say with certainty whether the genus is monomyarian or dimyarian.

Dimensions.—The specimens are extremely variable in size, and this feature, together with the shape, will be noticed in the specific descriptions.

Material.—I collected some twenty-five specimens, several of which bear a portion of the shell. The New Zealand Geological Survey has many specimens, mostly in the form of casts. They generally occur in a very unsatisfactory state of preservation, with most or all of the shell dissolved away.

Locality and horizon.—The genus seems to be confined to the Carnic beds and occurs in all localities, such as the Nelson district, the Hokonui Hills, Nugget Point, etc. Separated valves are found in the *Mytilus-problematicus* Bed.

Affinities.—I found considerable difficulty in attempting to determine the relationship of these curious bivalves. The anterior tongue-like projection of the right valve appears to be homologous with the anterior auricle of the Myalinidæ, to which group the genus seems to belong. The anterior retreat or thickening of the margin of the left valve below the beak resembles that of *Pergamidia* Bittner,[1] a genus which occurs in the Upper Trias of Balia in Asia Minor; but in *Hokonuia* it extends over a less distance of the anterior margin than it does in *Pergamidia*.

The genus *Mysidia* Bittner[2] occurs also in the Upper Trias of Balia; but only right valves were known to Bittner, and they have a prominent tooth beneath the beak.

Hokonuia also recalls the genus *Mysidioptera* Salomon, a group of bivalves described as Mytiloid Limidæ, which occur in the Upper Trias of the Alps and other regions. In these, however, according to Bittner's illustrations, the byssal opening is similar in both valves. As a result of later research, however, Bittner shows that in *Mysidioptera* the area of the right valve is higher than that of the left.

The anterior ear of the right valve in *Hokonuia* recalls in some ways that which characterizes the left valve of *Eurydesma*, a form occurring in the Permo-Carboniferous marine beds of Australia and other regions of Gondwanaland.

As I can find no genus closely comparable with these New Zealand shells, I am compelled to institute a new generic name for them, and to regard them as having affinities with *Pergamidia*, *Mysidia*, and *Mysidioptera*, three *Lima*-like Myalinidæ of the Upper Trias of the Alps and Asia Minor.

It seems that a considerable number of species occur in New Zealand; but, owing to the poor state of preservation of the material, it is very difficult to separate these, or accurately to diagnose them. I offer descriptions of two species which seem to be the commonest and most distinctive.

HOKONUIA LIMÆFORMIS, sp. nov. (Pl. XXII, figs. 2 *a*, 2 *b*, & 5; Pl. XX, fig. 4.)

Shell rather higher than long, hinge-line straight, measuring about two-thirds of the length of the shell. Beak rather pointed,

[1] Bibliography, 6, xli, p. 103 & pl. iii, figs. 1–4.
[2] *Ibid.* p. 113 & pl. ii, fig. 10.

anteriorly situated and directed forwards, not projecting above the hinge-line. There is a curved truncation in front of and below the beak of the right valve, which extends for about a third of the length of the anterior margin and is bounded posteriorly by a raised ridge, on and behind which three or four faint radial ridges occur. The tongue-like projection of the right valve is directed towards the opposite valve at about a right angle from the plane of the right valve. The posterior wing is angular and flattened. The hinder margin is gently curved, the anterior margin more rounded, and the lower margin is well rounded. The growth-lines are prominent and irregular, and the surface of the shell towards the lower margin tends to become wavy and irregular.

Height = 75 mm.; length = 58 mm.; length of the hinge-area = 27 mm.; depth of right valve = 18 mm.

Locality and horizon.—Bed *c*, Otamita, Hokonui Hills. Carnic.

Remarks.—This is the most *Lima*-like of these shells, and recalls in general outline the recent *Lima excavata*. I have three right valves, all with portions of the shell; one of them with the left valve attached but lacking the beak; and a separated left valve.

HOKONUIA ROTUNDATA, sp. nov. (Pl. XX, figs. 5 *a* & 5 *b*; Pl. XXII, figs. 1, 3, & (?) 4 *a*, 4 *b*.)

Shell fairly thick, valves rather inflated and gently rounded, about as high as wide. Hinge-line considerably less than the width of the shell. The beak projects somewhat above the hinge-line, and is situated about the median line or rather in front of it. The posterior wing is rounded in outline, and is scarcely differentiated from the hinder margin of the shell, which is gently rounded. The anterior margin is rounded and rather produced, and the lower margin is gently rounded. There is a short, anterior, semicircular truncation below the beak of the right valve.

Growth-lines are well marked, and irregular ripples of growth occur especially towards the margin.

The anterior tongue-like process of the right valve is directed forwards, rather than directly downwards, away from the right valve.

A specimen with both valves measures 89 mm. in height and 84 mm. in length; the right valve is 21 mm. deep, and the hinge-line is 35 mm. long.

Locality and horizon.—Hokonui Hills. I have casts of two left valves, and another cast in which both valves are slightly displaced. I collected a left valve with the shell on it in the *Mytilus-problematicus* Bed at Nugget Point. The New Zealand Geological Survey possesses a cast of the anterior part of a right valve, from which I made a gutta-percha squeeze. Carnic.

Remarks.—This species is more rounded in outline than the last; the anterior truncation of the right valve is less extensive and more curved; and the tongue-like process is directed more forwards from the plane of the valve.

Pinna sp. (Pl. XXII, fig. 11.)

Shell thin, hinge-line straight, marginal outline broadly rounded behind. A bluntly-angular median ridge passes from the beak to the lower posterior margin. The concentric growth-ripples are well marked and closely set. Length = 80 mm.; height near posterior margin = 47 mm.

Locality and horizon.—Eighty-Eight Valley, Nelson. Carnic. The New Zealand Geological Survey Collection possesses two or three specimens.

Remarks.—This *Pinna* rather resembles *P. heeri*, J. Bœhm,[1] from the Upper Trias of Bear Island.

Pecten sp. (Pl. XXI, fig. 18.)

Shell thin, with comparatively large ears. A great number of fine, sharp, radial, slightly-wavy ribs start some distance below the beak, and pass to the margins; between these a number of exactly similar secondary ribs are developed lower down. Towards the lateral margins the ribs are somewhat more closely set. About five rather coarse ribs are present on the ear. The concentric growth-lines are numerous and closely set, but are fainter than the ribs. Length = 30 mm.; height = 28 mm.

Locality and horizon.—*Palæocardita* Bed, Nugget Point. Carnic. A single cast, from which I made a gutta-percha squeeze.

Remarks.—I am uncertain whether this is a left or a right valve; only one ear is well shown, and it seems different from the other one. The shell may possibly be an *Aviculopecten*. The absence of ribs on the umbonal portion may be due to erosion during life, or to conditions of fossilization. It recalls in some respects a *Pecten* from the *Pseudomonotis* Beds of Japan figured by Mojsisovics.[2]

Lima (Limatula) cf. pichleri Bittner. (Pl. XXI, fig. 16.)

1895. 'Lamellibranchiaten der Alpinen Trias' p. 192 & pl. xxii, fig. 21.

Outline oval and rather narrow, hinge-line wide, posterior and anterior ears about equally developed. Area not visible. It is decorated with fine, somewhat sharp, and wavy ribs, which pass from the beak to the margins. This shell agrees with the above-named species, but is less oblique in outline and the ribs are rather more wavy.

Locality and horizon.—Western slope of Mount Heslington, south of the Wairoa Gorge, Nelson. Carnic.

Cassianella sp. (Pl. XXI, fig. 19.)

Shell fairly thick, the beak arched and rolled, projecting above and rather over the hinge-line. The posterior wing is somewhat

[1] Bibliography, 8, p. 38 & pl. v, figs. 4–6.
[2] Bibliography, 33, p. 176 & pl. ii, fig. 9.

produced and pointed. The lower posterior margin is rounded and slightly produced; the upper anterior margin is apparently well rounded. The surface-decoration consists of fine, closely-set, rather foliaceous, concentric growth-lines.

Locality and horizon.—Bed *c*, Otamita, Hokonui Hills. Carnic. I collected a single left valve; unfortunately, the margins are somewhat damaged.

Remarks.—This specimen is too imperfect for a specific determination, but is undoubtedly a *Cassianella*.

Anodontophora. (Pl. XXI, figs. 8–10.)

The three bivalves which will now be described appear to belong to the genus *Anoplophora* of Sandberger: this is a preoccupied name, which Cossmann has replaced by that of *Anodontophora*, although, owing to the somewhat uncertain characters of the genus, the identification is not entirely beyond doubt.

Zittel[1] says of *Anoplophora* that the hinge-teeth are wanting, and that the hinge-margin is somewhat thickened in front of and behind the beak; the anterior muscular depression is heart-shaped and wide, the posterior one slightly sunken, and the pallial line is marginal and linear.

Dr. W. H. Dall[2] includes *Anoplophora* in the Cardiniidæ, and says that in the right valve there is a blunt, thick, cardinal tooth fitting into a socket in the opposite valve, and beside the socket a long posterior lateral tooth.

Bittner[3] says of the Himalayan form *Anodontophora griesbachi* that the test is thin near the umbones, and a slight filing was sufficient to prove that a strong hinge-plate with tooth-structure did not exist. He goes on to say that muscular impressions are tolerably distinct for the thin shell, and that a pallial sinus is not perceptible.

In my New Zealand examples, which I am able to group into three species, the shell is completely closed all round; in two of them it is very thin, but in the third rather thicker. I could detect no impressions, either of the muscle-scars or of the pallial line. As regards the dentition, a close examination of all the casts in my possession showed no trace of hinge-teeth; but there was evidence of a thickening of the hinge-margin below and behind the beak.

Locality and horizon.—They seem to be confined to the Carnic beds in New Zealand. I succeeded in collecting several specimens with the shell; but they generally occur as casts, and are often more or less distorted and crushed. Sir James Hector's identification of *Edmondia* in these beds seems to have been based on shells of this group.

[1] 'Handbuch der Paläontologie' vol. i, pt. 2, p. 62.
[2] Zittel's 'Textbook of Palæontology' [transl. Eastman] vol. i (1913) p. 452.
[3] Bibliography, 5, p. 60.

Anodontophora angulata, sp. nov. (Pl. XXI, fig. 10.)

Shell thin, elongated; the beaks anterior or terminal, projecting considerably above the hinge-area, strongly directed forwards, tapering and rolled, enclosing a deep false lunular depression beneath them, divided by the sharp margin of the valves. The anterior margin below the beak is well rounded, the lower margin very gently rounded, and the posterior lower margin rather angulated. The upper posterior margin is bluntly angular. A rather prominent angular ridge merging gradually into the surface of the shell passes from behind the beak to the lower posterior margin, causing the valves to be somewhat inflated. Growth-lines are fine and closely set, but rather irregular; otherwise the surface is smooth. Length = 31 mm.; height = 20 mm.; thickness of both valves = 17 mm.

Locality and horizon.—Bed *c*, Otamita, Hokonui Hills, where I collected several specimens, both as casts and with the shell preserved. Carnic.

Remarks.—This form is easily recognized by its elongate shape, nearly terminal beaks, and the strong ridge on the posterior portion of the valves.

Anodontophora ovalis, sp. nov. (Pl. XXI, fig. 9.)

Shell very thin; beaks rather anteriorly situated, rounded, broad, low, anteriorly directed and rolled, enclosing beneath them a deep, false, lunular depression. The anterior margin below the beaks is well rounded and rather produced; the posterior margin is broadly rounded. The valves are not inflated; the surface is gently rounded, and shows no ridge in the posterior portion.

The surface of the shell is fairly smooth with fine, but rather irregular, raised growth-lines, which become more strongly developed towards the margin. Length = 35 mm.; height = 25 mm.; thickness = 15 mm.

Locality and horizon.—Bed *c*, Otamita, Hokonui Hills. Carnic. I collected three specimens with the shell wholly or partly preserved.

Remarks.—This species resembles rather closely *Anodontophora griesbachi* Bittner,[1] which occurs in the *Tropites* Beds of the Bambanag and Shal-Shal sections of the Himalayan Upper Trias; but in the New Zealand shell the beak seems wider, blunter, and more anteriorly situated, and the growth-lines are coarser and less regular.

Anodontophora edmondiiformis, sp. nov. (Pl. XXI, fig. 8.)

The shell is fairly thick, but seems to have been thinner in the umbonal region. The beak is rather anteriorly situated, broad and blunt, anteriorly directed and inrolled, enclosing a small lunular depression. The margin is well rounded in front, slightly

[1] Bibliography, 5, p. 60 & pl. viii, figs. 14–16.

curved below, and broadly rounded behind. The surface of the shell is gently rounded, with fine, closely-set growth-lines, interrupted in places, especially towards the margin, by a larger growth-furrow. There is no radial sculpture or ridge. Length = 42 mm.; height = 29 mm.; depth of the left valve = 11 mm.

Locality and horizon.—Bed *c*, Otamita, Hokonui Hills. I collected a fine left valve and a smaller double-valved specimen, both with the shell preserved. Carnic.

Remarks.—This form differs from *A. ovalis* in its much thicker shell, more elongated shape, and larger size. The fine concentric growth-lines recall those on a specimen of *A. griesbachi* illustrated by Bittner; but the beaks are more anteriorly situated, and the shell is apparently thicker. I could not ascertain the characters of the hinge-area in my specimens.

Megalodon globularis, sp. nov. (Pl. XXI, fig. 17.)

Shell thick, rounded, tumid, and inflated, especially towards the hinder margin; the two valves together form a rather globular shell. The beaks are anteriorly situated, strongly directed forwards, produced to a point, and nearly touch one another. Below them is a deep, false, lunular depression. The shell-margin is gently rounded behind and below, but is slightly produced anteriorly below the lunule. The growth-lines are closely set and coarsely marked, and the growth of the shell is somewhat interrupted and irregular. The anterior muscle-scar is fairly strongly marked.

One specimen is 23 mm. long, 27 mm. high, and each valve is 15 mm. deep. A rather smaller right valve is 20 mm. long, 18 mm. high, and 8 mm. deep.

Locality and horizon.—I collected the casts and impressions of two specimens (one with both valves together and part of the shell remaining) on the north side of the entrance of the Wairoa Gorge in greywackes below the *Mytilus-problematicus* Bed. The other, a right valve, occurred a little way up the Gorge in the *Mytilus-problematicus* Bed. Lower Carnic. From both of these gutta-percha squeezes were made.

Remarks.—There seems to be no doubt that this shell is a *Megalodon*, the hinge-plate is thick and heavy; but I could not see the disposition of the teeth, neither could I ascertain whether the valves were quite equal or not.

Pseudoplacunopsis placentoides, sp. nov. (Pl. XXI, figs. 14 & 15.)

Bittner uses this generic or subgeneric name for shells outwardly resembling *Placunopsis*, but wherein the hinge-apparatus partakes of the character of that of *Spondylus* or *Plicatula*, and is formed by two ridges or auricular crura which diverge below the beak.

The shell here described comes under this generic definition.

It occurs fixed to the surface of other shells, but seems to have a partiality for attaching itself to the large Nautilids. The free or upper valve reproduces the sculpture of the shell to which it is attached. The lower sessile valve is very thin, and is closely attached by the whole of its surface. The crura diverge at about a right angle, and the margin of the valve is marked by a row of fine radiating furrows. The free or left valve is convex, and the growth-lines are irregularly spaced and well marked. The hinge-line is straight, and occupies almost the greatest width of the shell; but the area is obscure or absent.

Locality and horizon.—Bed *c*, Otamita, Hokonui Hills. Carnic. Prof. P. Marshall collected a large crushed *Gryphoceras*, which had a great part of its surface covered with these shells.

MYOPHORIA NUGGETENSIS, sp. nov. (Pl. XXII, fig. 10.)

The shell is sub-triangular in outline. The beaks are situated slightly forward of the median line, are pointed, close together, and turned very slightly but perceptibly backwards.

The anterior margin is rounded, the posterior lower margin somewhat prolonged and angular. The keel, which passes from the beaks to the lower posterior margin, is prominent, and the two parts of the shell separated by it make a rather sharp angle one with the other. The groove in front of and adjoining the keel is very slightly wider, but no deeper, than the other radial grooves, and a line of very small nodes passes down the middle of it. About eight ridges, broken by the growth-lines into nodes, pass from the beaks to the lower and anterior margin. Behind the keel the shell is almost flat, and is covered with fine growth-lines and small irregular pimples, which vary in size. A shallow furrow passes down the middle of the flat posterior portion. The posterior muscle-scar is suboval and deep on the side nearest the beak, but shallower towards its lower margin. The pallial impression is well marked.

The left valve has one very strong central triangular tooth, not perceptibly divided, but strongly grooved on both sides, eight grooves on the posterior and six on the anterior side; there is a very feeble anterior tooth, strongly grooved on its inner side, and a very thin posterior tooth scarcely differentiated from the shell-margin, not grooved. Length = 53 mm.; height = 47 mm.

Locality and horizon.—About ten specimens, from which the above diagnosis was drawn up, were obtained from a bed at Nugget Point, known to New Zealand geologists as the '*Trigonia*' Bed. It comprises about 15 feet of a very hard fine-grained greywacke rather low in the Carnic, about 700 feet below the *Mytilus-problematicus* Bed, and immediately above a thick bed of granitic conglomerate. The shells occur somewhat plentifully as single valves, or often with the two valves open or slightly displaced. They are difficult to collect, owing to the hardness of the rock; but, by preparation of the material and dissolution of the shell, satisfactory gutta-percha impressions were obtained.

Remarks.—I was undecided at times whether to regard this shell as a *Trigonia* or a *Myophoria*, but have finally come to the conclusion that it is a *Myophoria*. The striation of the hinge-teeth alone does not apparently make it a *Trigonia*, although the very slight but definite posterior inclination of the beaks in some, if not all, of the specimens is suggestive of *Trigonia*.

Two Triassic *Trigoniæ* have been recorded. Bittner in 1895 described *Tr. gaytani* (Klipstein) from the St. Cassian Beds, and placed it in the group of Costatæ; and J. Bœhm in 1903 described a very small form (*Tr. margaritifera*) from the Upper Trias of Bear Island in the Arctic Circle.

Myophoria otamitensis, sp. nov. (Pl. XXII, fig. 8.)

Shell rather small, beaks situated slightly behind the median line, medially directed. Margin rounded in front and below, slightly angulated behind, but not produced. A raised keel, bearing seven or eight coarse nodes, passes from behind the beak to the lower posterior margin. Behind this keel a shallow sulcus passes down the flank of the shell, rather more than halfway towards its posterior margin. The flank is decorated with raised tubercles of irregular size. In front of the keel, and almost adjoining it, is a fine raised ridge; in front of this are six very much more prominent ridges, which are cut by the concentric growth-furrows into a series of prominent rounded nodes. The young shell bears a series of concentric wavy ridges. Length = 18 mm.; height = 15 mm.

Locality and horizon.—The holotype is an excellently preserved specimen (with both valves and the test preserved) that I collected in Bed *c* at Otamita, Hokonui Hills. Carnic.

Fragments of casts, apparently of this shell, are common in the decomposed felspathic sandstones of the Carnic, near Gore, in the Hokonui Hills, and other localities. A form which may be identical occurs also in Noric beds, but is generally very badly preserved.

Myophoria heslingtonensis, sp. nov. (Pl. XXII, fig. 9.)

Shell small and finely sculptured, rounded in front, gently rounded below, but angulated at the lower posterior portion where the ridge joins the margin. An acute raised ridge passes from behind the beak to the lower posterior margin, in front of which there is a wide sulcus. The middle part of the shell bears six or seven faint radial ridges, which become progressively fainter as they approach the anterior margin. These are crossed by a series of very regular concentric ridges and furrows forming a series of raised points. Behind the ridge the flank is decorated with fine raised points. Length = 7 mm.; height = 6 mm.

Locality and horizon.—Mount Heslington, south of the Wairoa Gorge. Carnic. The holotype consists of a piece of hard felspathic sandstone belonging to the New Zealand Geological Survey, having three or four casts on its surface, from which I made a gutta-percha squeeze.

PALÆOCARDITA QUADRATA, sp. nov. (Pl. XXI, fig. 11.)

Shell thick, strongly arched, with a high rounded ridge passing from the beaks to the lower or hinder margin and merging into the rounded surface of the shell. Beaks prominent, rather anteriorly situated, tapering, and rolled. Shell-margin rounded in front, bluntly angulate behind, and rather less sharply angulate below where the ridge joins the lower margin. The marginal outline and the position of the beaks vary somewhat in different examples. The upper posterior margin is not alate.

Sixteen or seventeen sharp, raised, radial ribs pass from the beak to the margins, the shallow sunken furrow between them in well-preserved specimens is marked with very fine, sharp, regular, closely-set, concentric growth-lines which also cross the ribs. The anterior muscle-scar is deep and well marked, and is situated closely adjoining the upper anterior margin.

A left valve from Nugget Point is 20 mm. long, 18 mm. high. A right valve from Otamitais 18 mm. long, 16 mm. high, and 8 mm. deep.

Locality and horizon.—I collected many specimens with badly-preserved test in a loose block of very hard, coarse, felspathic sandstone on the shore at Nugget Point; but I traced the bed in the cliff where it occurs above the *Mytilus-problematicus* Bed. Valves of *Hokonuia* sp., gasteropods, etc., occur also in the same deposit. I found a right valve in Bed *c* at Otamita with part of the shell very well preserved. Carnic.

Remarks.—*Palæocardita* is now regarded as connected with the Pleurophoridæ rather than with the Tertiary and recent *Carditæ*. The form now described is related to the Alpine forms of which Bittner records four species in the St. Cassian Beds. It is as strongly arched as *P. benecki* Bittner, but is much shorter and more quadrate in outline. It is more strongly arched than the common *P. crenata* Goldfuss, and the upper posterior portion of the shell is less expanded than in the Alpine species. In the Alps the *Palæocardita* Beds mark a horizon in the Carnic, and in New Zealand the genus seems to occupy an analogous position.

PLEUROPHORUS ZEALANDICUS, sp. nov. (Pl. XXI, fig. 6.)

Shell thick and solid, oblong and produced behind; the hinge-line is arched, and the surface of the shell is rounded. The beaks are very small and anterior, in some specimens terminal, and scarcely project from the regularly-rounded anterior outline of the shell. A broadly-rounded ridge passes from the beaks to the lower posterior margin, and between this and the hinge-margin occur two or three faintly-marked ridges. The lunule is obscure, but there is a long concave escutcheon behind the beaks. The concentric growth-lines are prominent, closely set, and regular. The anterior muscle-scar is deep and rounded, and the pallial impression is well marked. Length = 63 mm.; height = 25 mm.

Locality and horizon.—Bed *c*, Otomita, Hokonui Hills,

where it is common and very well preserved. It also occurs at Nugget Point and in the Nelson district. Carnic.

Remarks.—This large form recalls somewhat the Permian *Pleurophorus costatus*, but is larger, more rounded, and the hinge-line is more arched.

ANISOCARDIA PARVULA, sp. nov. (Pl. XXII, figs. 6 & 7.)

Shell thick, sub-circular, with rounded margins. Beak slightly in front of the median line, not very prominent, but there is a well-marked lunule in front of it. Five or six irregularly spaced growth-furrows occur, and about seventeen faint, slightly-arched ribs pass from the beak to the margin. The ribs are wanting on the hinder part, and become very faint on the front part, of the shell. A squeeze of the interior of a right valve shows a strong cardinal tooth and apparently another tooth in front of this one, and sockets about equally distant from the beak for an anterior and a posterior tooth. These sockets occur just above the muscle-scars; the anterior scar is deep and bounded by a ridge, the posterior scar is less strongly marked. The lower interior margin of the valve is crenulated. Length = 5·5 mm.; height = 5 mm.

This little shell seems to belong to the Cypricardiaceæ, and, with *Palæocardita* and *Pleurophorus*, forms the third representative of that group in the New Zealand Trias.

Locality and horizon.—Bed *c*, Otamita, Hokonui Hills. I also saw traces of it in the *Halobia-zitteli* Beds at Mount Heslington, near Nelson. It is a scarce form.

BRACHIOPODA.

The Brachiopoda of the New Zealand Trias afford an interesting and suggestive study. The Rhynchonellids seem all to belong to the essentially Upper Triassic group *Halorella* of Bittner, which have a more or less pronounced median sulcus in both valves. One species, apparently new, is very common in the Kaihiku Beds, but becomes much scarcer in the Lower Carnic. I have described only two forms of *Halorella*, but probably more of them occur. Among the Terebratulids the Palæozoic genus *Dielasma* occurs, apparently to the exclusion of all others, in the Kaihiku Beds, and seems to be represented by two species. It persists into the Carnic, but becomes much less conspicuous there. In the Carnic beds the Terebratulids of Mesozoic aspect, devoid of hinge-plate and median dorsal septum, become conspicuous.[1] There are several species, one of which is much thickened in the umbonal region and bears very thick hinge-teeth. Others seem to belong to more normal Mesozoic types; but, as the nature of the brachidia could not easily be seen, it is impossible to make any certain generic determination of them.

[1] W. Waagen mentions that, in the Upper Triassic Kœssen Beds of India, *Dielasma* is replaced by the genera *Rhætina* and *Zugmayeria*.

No true Spirifers occur in the New Zealand Trias: the spire-bearing forms are all referable to the genera *Spiriferina*, *Cyrtina*, *Mentzelia*, *Mentzeliopsis*, gen. nov., *Retzia*, *Spirigera*, and *Hectoria*, gen. nov. *Spiriferina* begins in the Kaihiku Beds with a small form belonging to the group of *Sp. fragilis* Schlotheim, which occurs in the German, Alpine, and Himalayan Muschelkalk. Both *Sp. fragilis* and a large and rather alate form are confined to these beds. In the Carnic a series of conspicuous sharply-alate forms occur, but in the Rhætic beds an extremely long-winged form, *Sp. diomedea*, sp. nov., occurs in association with the Spirigerid genus *Hectoria*. Bittner expressed his surprise on finding in the Himalayan Trias a *Spiriferina* so alate as *Sp. stracheyi* Salter, which he compares in this respect with the Permian *Spirifer alatus*. The New Zealand Trias is characterized by some very much more sharply-alate forms, which represent a morphic equivalent of the long-winged Spirifers of the Palæozoic. Some, however, are more acutely winged than even the most alate of the true Spirifers.

Various *Spiriferinæ* occur, in which the ventral septum and the dental plate assume the Cyrtiniform arrangement. These include the *Psioidea* group of Hector, and some of them resemble certain forms of the Alpine Rhætic.

A *Retzia* of the group of *R. schwageri* Bittner, a rather wide-spread form in the Alps and Himalayas, occurs in the Carnic. Other *Retziæ* also seem to be present, but my specimens are not well enough preserved for description. *Mentzelia* is intermediate in some ways between *Martinia* and *Spiriferina*. The shell is silky and fibrous, and at the same time faintly punctate; a sharp median septum and dental plates are found in the ventral valve. I collected two species of *Mentzelia* high up in the Rhætic at Kawhia: one with a smooth *Martinia*-like shell, and the other faintly ribbed. They should be searched for at lower horizons and in other localities in New Zealand.

One of the commonest brachiopods in the Kaihiku Beds is a *Mentzelia*-like form having both valves covered with tubular spines. It seems to be quite new, and so I have instituted a new genus for it, and have called it *Mentzeliopsis*. It apparently occurs only in the Kaihiku Beds.

The representatives of the Athyrid or Spirigerid group are especially interesting. *Spirigera kaihikuana*, sp. nov., is confined to the Kaihiku Beds, and belongs to the group of *Sp. wreyi* already described by Zittel, but occurring on a Carnic horizon. In the Carnic a form occurs, which is related, as regards the thickening of the hinge-region and cardinal process, to *Spirigera oxycolpos* Emmrich, the largest and latest of the Alpine Athyrids confined to the Rhætic Kœssen Beds.

A still more specialized group, to which I have given the name *Hectoria* (subgenus *Clavigera* of Hector), begins in the Carnic, and becomes exceedingly common in the Rhætic. They are related to *Spirigera oxycolpos*; but they are bisulcate, and have a still more

exaggerated development of shelly matter in the hinge-area and cardinal process. The group persists into Jurassic times, the first instance known to me of a Spirigerid in the Jurassic.

The appearance in New Zealand, on so low a horizon as the Carnic, of brachiopods presenting a decidedly Rhætic aspect, such as the group of *Spirigera oxycolpos* (including the new genus *Hectoria*), and *Spiriferinæ* of the group of *Sp. suessi* and *Sp. austriaca* and others with the Cyrtiniform septal structure, impresses the Upper Triassic Brachiopod fauna of New Zealand with Rhætic affinities. It suggests that some of the European Rhætic forms may have originated in the Southern Hemisphere or round the shores of Gondwanaland. On the other hand, a *Mentzelia* very like the European Muschelkalk form *M. mentzeli* occurs high in the Rhætic in New Zealand. The value of the Brachiopoda for zonal purposes in the New Zealand Trias seems to be limited.

It is significant to find in the New Zealand Trias certain phyla of the Brachiopoda towards the last stages of their existence developing an excess of shelly matter in the following respects:—

(*a*) In the *Spiriferinæ*, in the form of extremely-alate shells and correspondingly lengthened spiralia.
(*b*) In the *Mentzeliæ*, as a covering of tubular spines.
(*c*) In the *Spirigeræ*, as an enormously-enlarged cardinal process and a greatly-thickened hinge-area.

Rastelligera, Psioidea, and Clavigera.

A few remarks dealing with these subgenera of Hector[1] are necessary in discussing the Brachiopoda of the New Zealand Trias.

Rastelligera embraced a group of alate *Spiriferinæ*, having a row of vertical rake-like teeth arranged along the hinge-area. The comb-tooth structure is certainly very apparent in many of the New Zealand *Spiriferinæ*, but especially so in the very alate form that I have called *Spiriferina diomedea*. Since, however, it is visible also in many true *Spiriferæ* of the Palæozoic, as well as in *Spiriferina*, it cannot be regarded as of generic significance. In some at least of the specimens that I examined I concluded that the shell-surface had been partly decomposed and the outer layer destroyed previous to fossilization. This surface-erosion seems to have taken place readily in the coarser sediments. In one specimen the central part of the area showed the comb-like structure; while towards the wings the outer surface remained, and was longitudinally striate as in an ordinary Spirifer. The structure certainly does not appear on the alate *Spiriferina kaihikuana* of the Kaihiku Series, and in consequence Hector concluded that *Rastelligera* was absent from those beds; but I am inclined to think that the greater fineness, or more rapid deposition, of sediment in those beds prevented the surface-decomposition of the shell.

Psioidea designates, according to Hector, *Spiriferinæ*, varying

[1] Bibliography, 16.

greatly in width of the hinge-line, in which the dental plates join the median septum. Zugmayer[1] describes several such *Spiriferinæ* from the Alpine Rhætic, and includes them in his group of Dimidiatæ, separating them from the genus *Cyrtina*, in which this septal and dental peculiarity also occurs, apparently on account of their concave and uncovered delthyrium. The Cyrtiniform septal arrangement is apparently a phylogerontic feature, and seems to have arisen independently in several phyla of *Spiriferinæ* Hector's subgenus includes forms which closely resemble the Alpine Rhætic *Spiriferina suessi* and *Sp. austriaca*, and new forms which I have named *Sp. nelsonensis* and *Sp. otamitensis*. The early appearance of these forms in the New Zealand Trias is a remarkable feature.

Clavigera represents a group of specialized bisulcate Spirigerids the affinities of which are discussed later on. I have considered it advisable to rename this group, and have called it *Hectoria*. Hector's description was published without any illustrations, and his subgeneric name closely resembles that of *Claviger* given to a group of the Melanias.

HALORELLA ZEALANDICA, sp. nov. (Pl. XXIII, figs. 1*a*–3.)

Beak prominent, the hinge-line sloping rapidly away from it on each side, giving the shell a subtriangular outline. The delthyrium is triangular and insunken. In the ventral valve is a broad median sulcus with a flattened floor, on which two (or, in some specimens, four) small rounded folds occur, and continue from about a third to half of the distance to the beak. The sulcus is bounded on each side by a broad rounded fold, which continues about halfway to the beak, and two similarly rounded, but much shorter, lateral folds on each side. The dorsal valve has a broad median depression, but it is rather flattened than sunken, and bears two (or, in some specimens, three) narrow rounded folds on it, which continue for only about a third, or rather more, of the length of the shell from the anterior margin. The median depression is bounded by two broad, rounded, lateral folds which reach about halfway to the beak, and there are two more rounded but shorter lateral folds.

Dental plates are well developed in the ventral valve, and in the dorsal valve there is a sharp median septum which extends from the beak about halfway to the anterior margin. Growth-ridges are well marked, but widely spaced.

This species varies somewhat in shape and dimensions, and in the number of secondary ribs on the median sulcus; some specimens are wider, and have a less prominent beak than others. One example is 16 mm. long and 15 mm. wide; another is 13 mm. long and 13 mm. wide; a third is 13 mm. long and 15 mm. wide.

Locality and horizon.—It is common in the Kaihiku Beds at all localities. I collected many casts and impressions at

[1] Bibliography, 52.

Caroline Cutting in the Hokonui Hills. It persists into the Carnic beds, but becomes much scarcer.

Remarks.—I think that this shell should be placed in Bittner's group *Halorella*, although the dorsal median sulcus is rather flattened than sunken. In outline it recalls *H. pedata* var. *coarctata* Bittner of the Alpine Trias, but in that form the ribs continue from the anterior margin to the beak.

HALORELLA sp. (Pl. XXIII, fig. 4.)

A single fragmentary dorsal valve has a very faint median sulcus and about twenty very regular ribs, all of about equal height. The sulci between the ribs are of equal depth. The lateral ribs become curved as they approach the anterior lateral margins, and all ribs extend to the beak region. There is a short median dorsal septum.

Locality and horizon.—Eighty-Eight Valley, Nelson. Apparently from the *Mytilus-problematicus* Bed. New Zealand Geological Survey Collection. Carnic.

Remarks.—This *Halorella* belongs to the group of *H. pedata* Bronn and *H. amphitoma* Bronn. It seems to agree best with *H. pedata* var. *multicostata*, which has twenty or twenty-four ribs. These forms occur in the Alps in the Hallstatt and Dachstein Beds. J. Wanner[1] records a very similar variety of *H. amphitoma*, with about eighteen ribs, from North-Eastern Serang in the Malay Archipelago.

DIELASMA cf. HIMALAYANA Bittner.

1899. 'Trias Brach. & Lamellibranch.' Pal. Ind. ser. 15, vol. ii, pt. 2, p. 25 & pl. v, figs. 1–8, 10, 11.

Small forms of rounded or oval outline occur plentifully as casts in the lower strata of the New Zealand fossiliferous Trias. The shell bears none or only a very faint plication, and gutta-percha squeezes show that the growth-lines are closely set and well marked. The dental plates of the ventral valve and the median septum of the dorsal valve are well developed.

They are generally of small size, and are not strongly inflated: one specimen is 11 mm. long and 10 mm. wide.

Locality and horizon.—This form is plentiful in the Kaihiku Beds at Caroline Cutting and other localities; and I found casts of this or a very similar small *Dielasma* in the *Halobia* Beds at Mount Heslington, but they become very scarce in the Carnic.

Remarks.—This form recalls the Permian *D. elongata* Schlotheim, but I think that it is identical with *D. himalayana* Bittner, which occurs in the main complex of the Muschelkalk and in the beds with *Spiriferina stracheyi* Salter in the Himalayas.

DIELASMA ZEALANDICA, sp. nov. (Pl. XXIII, fig. 5.)

Shell elongated, the outline tapering gradually towards the beak, but expanding towards the anterior margin, which is well rounded.

[1] Bibliography, 49, p. 187 & pl. vii, fig. 8.

Valves somewhat flattened. The beak is prominent, but receding; the foramen is large and rather diagonally situated, having encroached on the beak through absorption or wear. The delthyrium seems to have been partly covered by the dorsal beak. The dorsal valve bears near its anterior margin a very faint, broad, mesial fold and lateral sulci. Owing to the extremely-slight plication, the junction of the valves is nearly straight. The growth-lines are well marked on the cast.

Dental plates are well developed in the ventral beak. In the dorsal valve a strong median septum extends for more than a third of the length of the shell, and supports a prominent shield-like hinge-plate.

Length = 46 mm.; width = 33 mm.; thickness = 16 mm.

Locality and horizon.—Kaihiku Beds, Caroline Cutting, Hokonui Hills. Two casts were collected, one of them crushed.

Remarks.—This form differs from the numerous small Dielasmas in the Kaihiku Beds, in its very much larger size and more prominent beak. I could not ascertain either the structure of the crura, or the nature of the shell. Although it is only a cast, its distinctive characters justify the attribution to it of a specific name.

Cœnothyris sp. (Pl. XXIII, fig. 7.)

Shell subpentagonal in outline, rather inflated; the beak tapering slowly, fairly prominent, and bent over so that the area and part of the foramen are hidden by the dorsal beak. The dorsal valve has a broad and high median fold, bounded on each side by a broad and shallow sulcus, which merges into the rounded surface of the shell. Near the anterior margin the median fold has a faint sulcus on it.

The internal cast shows that dental plates are well developed, but apparently in part calloused. There is a slight median septum in the dorsal valve, but nothing of the loops could be seen.

Length = 30 mm.; width = 28 mm.; thickness = 17 mm.

Locality and horizon.—A single specimen in my collection occurred in the *Pseudomonotis-richmondiana* Beds at Richmond, near Nelson. Noric. A gutta-percha squeeze of the beak and dorsal valve was obtained from the mould.

Remarks.—This large plicated Terebratulid is the only fossil that I ever saw associated with *Pseudomonotis richmondiana*, and is the only deeply-plicated Terebratulid that I obtained in the New Zealand Trias.

'Terebratula' pachydentata, sp. nov. (Pl. XXIII, fig. 6.)

Shell oval and gently rounded in outline; the valves are somewhat flattened and not inflated, and show no plication. The beak projects but very slightly above the hinge-area, and the foramen is very small. The growth-lines are fairly well marked. The shell is remarkably thickened in the umbonal region of the ventral valve,

the dental plates being massive and calloused. The hinge-teeth are large and broad, and become very conspicuous in the crushed specimens. The dorsal valve appears to have had a large cardinal process and wide dental sockets. The loops seem fairly long, but nothing definite of their structure could be seen.

Locality and horizon.—Bed *c*, at Otamita, Hokonui Hills, where I collected three or four well-preserved specimens with the shell on. One specimen is 27 mm. long and 23 mm. wide; another is 21 mm. long and 18 mm. wide.

Remarks.—The shelly thickening of the hinge-region of this shell points to its being some phylogerontic form, but of which generic stock I could not determine. The shell has a fibrous structure, and bears dark closely-set punctations.

TEREBRATULA cf. HUNGARICA Bittner. (Pl. XXIII, fig. 8.)

1890. 'Brachiopoden der Alpinen Trias' p. 278 & pl. xxvi, figs. 2–3.

A single specimen is oval in outline, rather inflated, but not plicate. The area and beak are rather prominent, and the foramen is small. The surface is smooth, with occasional regular growth-furrows. Length = 12 mm.; width = 11 mm.; thickness = 6 mm.

Locality and horizon.—Bed *c*, Otamita, Hokonui Hills. Carnic. One specimen in my collection.

Remarks.—This specimen could not be sacrificed in order to investigate the internal structure; but in outward appearance it resembles the above-named species, which occurs at high Triassic horizons in the Eastern Alps.

SPIRIFERINA FRAGILIS Schlotheim. (Pl. XXIV, figs. 10–12.)

1890. A. Bittner, 'Brachiopoden der Alpinen Trias' p. 29 & pl. xxxv, figs. 2–4.

The hinge-line in most examples represents the greatest width of the shell. In the ventral valve the area is high, wide, and triangular, flat or slightly concave, and the beak is but slightly bent over the area. The median sulcus is deep and angular, and is bounded by more or less angular folds, on each side of which are three lateral folds, the last one often very small. The area of the dorsal valve is obscure; the beak is small, and projects but slightly above the area. The median fold is appreciably higher and wider than the lateral folds, of which there are three or four on each side of it, the last one being very small. Concentric growth-lamellæ are prominent, and become foliaceous towards the anterior margin. Length = 16 mm.; width = 19 mm.

In another dorsal valve of a slightly-different variety (fig. 12) the outline contracts very slightly below the hinge-line and then widens out again, becoming somewhat wider than at the hinge-line. At the hinge-line the shell is 17 mm. wide, but widens out to 18 mm. below that, and is 15 mm. long.

Locality and horizon.—This form is confined to the Kaihiku Beds, in which it occurs commonly in most localities. I collected

a series of casts at Caroline Cutting, from which I made gutta-percha squeezes.

Remarks.—It closely resembles *Spiriferina fragilis*, except that the beak seems rather less bent over the area than in the typical European form. Bittner describes a form called *Spiriferina lilangensis* Stol. from the Muschelkalk of the Spiti district of the Himalayas, and remarks on its similarity to *Sp. fragilis*; but the New Zealand specimens seem to resemble the European rather than the Himalayan form. *Sp. fragilis* was first described from the German Muschelkalk. In the Alps it occurs at Wengen in Upper Ladinic beds, according to Bittner. Piroutet records it from New Caledonia.

SPIRIFERINA KAIHIKUANA, sp. nov. (Pl. XXIV, fig. 15.)

The area is broad, and extends the whole length of the wings. Some specimens are more sharply alate than others; but in all of them the hinge-line represents the greatest width of the shell, and the margin contracts rapidly in front of the wings. The ventral valve has a broad, concave, median, rapidly-widening, dorsal furrow with about six low rounded folds on each side of it. The dorsal valve has a broad, rounded, median fold with five (in another specimen seven) low rounded folds on each side, which gradually diminish in size. The folds occupy the surface of the shell nearly to the hinge-area. The growth-lines are rather coarse. Casts show that the posterior part of the inside of the ventral valve was much filled in with shelly matter, and that there was a sharp median septum.

One specimen measures 72 mm. across the wings and 41 mm. in length; another less alate example is 46 mm. across the wings and 30 mm. long.

Locality and horizon.—This is the only large and alate *Spiriferina* that occurs in the Kaihiku Beds, to which it seems to be confined. The Geological Survey possesses some very fine specimens, of which, unfortunately, only the internal casts have been preserved. Hector illustrates one of these casts as *Trigonotreta alata*,[1] the English Permian form. It comes from the Crinoid Beds at Cowan's Railway Station, Oreti Valley.[2] From another specimen found at Eighty-Eight Valley, Nelson, I was able to make a gutta-percha impression of the exterior of the dorsal valve. I collected some smaller examples at Caroline Cutting.

Remarks.—This shell occurs in a rather fragmentary condition in the Kaihiku Beds; but, so far as I can ascertain from the material, the fragments all represent one species, despite variation in the length of the wings and in the number of the lateral folds. It shows some affinity with the small *Spiriferina fragilis* which accompanies it, in the width of the area and in the continuation of the ribs up to the area-margin. The only described form

[1] Catal. Ind. & Col. Exhibition (1886) p. 76, fig. 3.

[2] Prof. P. Marshall and I think that this is the same locality as Caroline Cutting, the name of the station having apparently been changed since the early survey was made.

with which I can compare it is *Spiriferina stracheyi* Salter from the Himalayan Muschelkalk, which Bittner says is rather closely related to the European *Sp. fragilis*; but the form here described is much larger, and is more strongly ribbed.

SPIRIFERINA GYPAËTUS, sp. nov. (Pl. XXIV, fig. 4.)

Shell extremely alate, the wings towards their apices tapering rapidly to sharp points. The ventral area is very long, concave, and narrow, and is faintly striate. The beak of the ventral valve is very small, and projects but slightly above the hinge-area; it practically touches that of the dorsal valve, which is broad and projects slightly above the dorsal area.

The dorsal valve has a broad, median, triangular, rapidly-widening fold, with a fairly-deep angular sinus on each side of it. The first lateral folds on each side are lower and rather narrower than the median one, and on either side of these are three much smaller and fainter lateral folds which gradually decrease in size. All the folds continue to the beak. The wings towards the apices are free from folds. The anterior outline of the shell is gently rounded, and narrows rapidly towards the wings, which continue very narrow for some distance, ending in sharp points. The growth-lines are prominent, irregularly spaced, and rather foliaceous.

Length = 22 mm.; width = 75 mm.

Locality and horizon.—A very fine cast of the ventral beak and dorsal valve, from which I made a gutta-percha squeeze, comes from the slopes of South Peak (Benmore), in the Hokonui Hills, and belongs to the New Zealand Geological Survey. The horizon is probably Noric.

SPIRIFERINA ACUTISSIMA, sp. nov. (Pl. XXIV, fig. 3.)

Shell extremely alate; the wings are produced into very acute points. The hinge-area extends the whole length of the wings, is very narrow, concave, and faintly striate parallel to the margin. The ventral beak is very small, and projects but slightly above the hinge-area; that of the dorsal valve is also small, and scarcely projects above the dorsal area, and the two almost touch one another.

In the dorsal valve the median fold is high, narrow, and triangular, and has a very faint median sulcus on its anterior portion. On each side of it are six similar folds gradually decreasing in size and height, the last being very faint. The folds continue to the dorsal beak, and are divided by rather deep and angular sulci. The anterior margin is very narrow in proportion to the width of the shell, the lateral margins narrowing gradually to the wings, which are considerably produced and end in very fine points. The growth-lines are not very prominent.

Length = 21 mm.; width = 83 mm.

Locality and horizon.—The New Zealand Geological Survey possesses a very fine mould of the ventral beak and dorsal valve in hard dark greywacke, from which I took a gutta-percha squeeze.

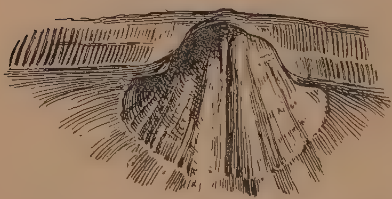
It comes from the east side of Mount Heslington, south of the Wairoa Gorge, but there is no other fossil on the piece of rock to indicate its horizon, which is probably Upper Carnic or Noric. I collected a rather weathered cast of a smaller dorsal valve in felspathic sandstone in Bed *a*, Otamita, Hokonui Hills, which is probably Lower Noric.

Remarks.—Both this and the last species are remarkable for the very narrow ventral area, the slight prominence of the ventral beak, and the fact that the apices of the wings end in acute points.

SPIRIFERINA DIOMEDEA, sp. nov. (Pl. XXIV, figs. 1 & 2.)

Shell extremely alate, about five times as wide as it is long, the wings narrowing gradually to the apices. The area extends the whole length of the wings: it is broad and high, and shows the comb-tooth structure along its whole length; but whether the serrated structure was exposed in the living shell, or whether during life it was covered with an easily decomposable layer of shell, I am not able to say with certainty. The ventral beak is blunt, wide, and rather prominent; that of the dorsal valve is broad, and projects very faintly above the hinge-line. The ventral valve has a rather broad, shallow, median sulcus, and on each side three or four lateral sulci, only slightly smaller and no deeper than the median one. The dorsal valve has a wide and low, triangular, rapidly-widening fold, which extends to the beak, and bears a slight median depression towards the anterior margin. On each side are four narrower rounded folds of equal height, which gradually decrease in size. The wings are free from folds towards the apices. The delthyrium is wide, open, and triangular. The median septum of the ventral valve is sharp but low, and extends for about three-quarters of the distance to the anterior margin; it lies in a well-marked hollowed-out depression which accommodates the muscle-scars, but these are not strongly marked.

Fig. 3.—*Gutta-percha squeeze of the interior apex of the ventral valve of* Spiriferina diomedea, *sp. nov. Rhætic. South Hillend, Otago.*



[This shows the sunken pit occupied by the pedicle and muscle-scars and median septum, also the area bearing the 'comb-tooth' structure upon which the subgenus *Rastelligera* was founded.]

Length = 26 mm.; width = 127 mm.

Locality and horizon.—The New Zealand Geological Survey possesses a cast of a ventral valve in coarse felspathic grit, from the north-western branch of Taylor's Creek, in the Hokonui Hills. This form occurs plentifully in the highest Trias with *Hectoria bisulcata* at the southern end of Roaring Bay, Nugget Point, in

a hard pebbly sandstone, which stands out as a stack in the coast-section; but specimens are very difficult to collect, the rock being so hard. The Survey, however, possesses a fairly-good specimen from this locality (Pl. XXIV, fig. 2). Prof. P. Marshall has recently sent me a piece of felspathic sandstone from South Hillend, 12 miles south of Benmore railway-cutting, on the south side of the Hokonui Hills, with several casts of this shell, from which I was able to make gutta-percha squeezes (fig. 1). It seems to be the same bed as that in the Benmore cutting, and contains casts of a large *Hectoria*. Rhætic.

Remarks.—This is the largest and latest, as well as by far the most alate, of the New Zealand Triassic *Spiriferinæ*. It differs from the two previously-described species in its larger size and in the wings narrowing very gradually to the points. The folds are lower and more rounded, and decrease gradually in size, the area also is broader, the ventral beak higher, and it occurs on a higher horizon than the two previously-described forms, which are of Carnic and Noric age.

SPIRIFERINA NELSONENSIS, sp. nov. (Pl. XXIV, figs. 6–8.)

Shell alate, valves rather inflated, the anterior margin is gently rounded in outline. The ventral valve has a broad median sulcus, which extends to the beak, and is bounded on each side by four rounded slightly-raised ribs, which decrease gradually in size. The dorsal valve has a triangular median fold, which increases rapidly in width, and on each side of it four fainter rounded ribs which are continued nearly to the beak.

The area of the ventral valve is wide, high, and concave; it is longitudinally striate, and represents the greatest width of the shell, the margin of the valves converging rapidly in front of the area. The delthyrium is triangular, wide, and open, bounded on each side by dental plates, which converge together inwards and meet the median septum: this latter is visible at the bottom of the open delthyrium as a thin plate projecting slightly above the line of junction of the dental plates. The surface of the dental plates is faintly furrowed. On both sides of the delthyrium another slightly-sunken triangular area is separated off, and is ornamented with faintly-impressed vertical furrows. The dorsal area is narrow, and a 'comb-tooth' structure is seen for a short distance on each side of the dorsal beak. The growth-lines are fairly well marked.

Length = 23 mm.; width = 45 mm.

Locality and horizon.—I collected three or four specimens in the *Halobia* Beds on the western slope and crest of Mount Heslington in the Nelson district. The New Zealand Geological Survey possesses a specimen from the same locality. Carnic.

Remarks.—Zugmayer divides his group of Rhætic 'Dimidiatæ' into two 'form groups' (Formenkreise): namely, the group of *Spiriferina uncinata* and that of *Sp. suessi*, the latter including only the single species. The species here described apparently

belongs to the first group, which comprises forms with vertical striæ on the dental plates and on the adjacent areal portion on each side of them: these, Zugmayer thinks, may have assisted in attaching a ligament or external muscle. He illustrates three species that show this peculiarity: namely, *Sp. uncinata*, *Sp. kœssenensis*, and *Sp. austriaca*; but they are all non-alate forms with a very high ventral area.

SPIRIFERINA cf. AUSTRIACA Suess. (Pl. XXIV, fig. 5.)

1882. H. Zugmayer, 'Untersuchungen über Rhätische Brachiopoden' p. 28 & pl. iii, figs. 6 *a*–6 *c*.

Shell about as long as it is wide. Ventral area high and triangular, slightly concave, and coarsely striate parallel to the hinge-margin, which represents very nearly the greatest width of the shell. The delthyrium is triangular and deeply sunken, the septal arrangement is cyrtiniform, and the thin median septum is seen towards the apex projecting above the floor of the delthyrium. The ventral beak is bent slightly over the areal region; the dorsal beak is rounded, rather inflated, and projects slightly above the hinge-area.

The dorsal valve is semicircular in outline, and has a raised, rather narrow, median fold, and three or four much fainter lateral folds, which cover the shell nearly to the hinge-margin. The ventral valve has a broad and shallow triangular median sulcus, which extends to the apex and is bounded by two raised narrow folds, on each side of which are two or three much fainter lateral folds.

Length = 38 mm.; width = 38 mm.

Locality and horizon.—The New Zealand Geological Survey possesses a specimen from Mount Potts, from which the above description was made. The shell is well preserved; but the delthyrium is nearly filled up with rock, and part of the dorsal valve is concealed. I am not sure whether it comes from the Kaihiku Series or from the Lower Carnic, but it is probably from the latter. I have three or four smaller, separated, single dorsal valves apparently belonging to this species, some of which have a faint fourth lateral fold. I collected them in low Carnic beds on the north side of the entrance of the Wairoa Gorge.

Remarks.—The attribution of this brachiopod to the above Alpine species is conjectural, but it evidently belongs to the group of *Sp. uncinata* and *Sp. austriaca*; the former, however, has a series of vertical striæ on the area next to the delthyrium, which is wanting in the present form and in *Sp. austriaca*, but is found in the form last described, *Sp. nelsonensis*. In general shape it resembles *Spiriferina austriaca*, which occurs in the Starheimberg Beds of the Alpine Rhætic.

Hector[1] illustrated a drawing of the specimen from Mount Potts under the title of '*Spiriferina (cristata?)*,' the small English Permian fossil, a very different species: this gave rise to

[1] Catal. Ind. & Col. Exhibition (1886) p. 76, fig. 6.

the idea that the Mount-Potts Beds were of Permian age, an idea further supported by the supposed occurrence of *Glossopteris* in these beds.

SPIRIFERINA OTAMITENSIS, sp. nov. (Pl. XXIV, figs. 9*a* & 9*b*.)

Both valves are about equally convex and slightly inflated. The hinge-line represents in some examples the greatest, in others nearly the greatest, width of the shell. The ventral beak projects but slightly above the hinge-area. The ventral area extends the whole length of the hinge-line, is moderately high, concave, and faintly striate parallel to the margin. The delthyrium is open and sunken, and the arrangement of dental plates and median septum is cyrtiniform. In one specimen the apex of the ventral valve is considerably thickened by a deposit of shelly matter.

The anterior and lateral margins are gently rounded, the outline forming more or less a semicircle. The dorsal valve has a rounded, gradually-widening, median fold, with four lateral folds on each side decreasing gradually in size. The median and the first two lateral folds extend to the beak, but the last two lateral folds die away before reaching it. The ventral valve has a rounded, fairly-deep median sulcus, bounded on each side by five rounded narrow folds gradually decreasing in size, the last two of which are very faint and do not reach the beak. The growth-lines are well marked.

Length = 20 mm.; width = 27 mm.

Locality and horizon.—Bed *e*, Otamita, Hokonui Hills, with *Halobiæ* of the group of *H. zitteli*. I collected several specimens bearing the shell, but they are more or less crushed or flattened in the shale.

Remarks.—This species belongs to the *Sp.-uncinata* group of the Dimidiatæ, but differs from *Sp. nelsonensis* and *Sp.* cf. *austriaca* in having a much narrower hinge-area and a less prominent ventral beak, and also from the former in the absence of a vertically-sulcate areal portion on each side of the delthyrium.

SPIRIFERINA SUESSI var. AUSTRALIS, nov. (Pl. XXIV, figs. 13*a*–14.)

1882. H. Zugmayer, 'Untersuchungen über Rhätische Brachiopoden' p. 29 & pl. iii, figs. 14–19.

The ventral valve is semipyramidal in shape, and more or less semicircular in outline. The ventral area is almost vertical, triangular, wider than it is high, flat or very slightly concave, and faintly striate parallel to the hinge-area. The ventral beak scarcely projects above the area; the delthyrium is triangular and deeply sunken; on each side of it a very narrow triangular area is marked off and slightly sunken, and is faintly furrowed longitudinally. In casts of the ventral beak the single incision of the median septum is seen extending forwards for about a third of the length of the valve.

The surface of the ventral valve bears a deep, angular, rapidly-

widening sulcus, which extends to the apex and is bounded on each side by a slight, rounded, raised fold. The dorsal valve has a strong, raised, roof-like, rapidly-widening, triangular fold, which extends to the beak and is bounded on both sides by a narrow sulcus. The growth-lines are faint, but well marked.

Length=18 mm.; width=20 mm.

Locality and horizon.—The crest of Mount Heslington, south of the Wairoa Gorge, in fine, brown, decomposed greywackes, with *Halobiæ* of the group of *Halobia zitelli*. I collected several specimens, both casts and moulds; but it is not a common form. Carnic.

Remarks.—This species forms the second group of Zugmayer's Dimidiatæ, in which the dental plates do not reach the back of the ventral beak, but join the edge of the median septum where it passes towards the area, forming a triangular sunken trough in the areal region. This arrangement obtains also in the Palæozoic genus *Cyrtina*, from which Zugmayer separates his Dimidiatæ, apparently on account of differences in the delthyrium. He gives a detailed description of *Spiriferina suessi*, which in the Alps seems to be confined to the Kœssen facies of the Rhætic. The New Zealand form appears to be slightly different in shape, the sides meeting the hinge-area at almost a right angle; but the differences do not seem to warrant a new specific name for it. A slight difference, however, is the presence on each side of the delthyrium of a very narrow, triangular, vertically-sulcate area, which Zugmayer says is absent in the Alpine *Sp. suessi*, but occurs in *Sp. uncinata*. I regard the present form as a local variety of *Spiriferina suessi*.

A drawing which Hector[1] published under the name of '*Psioidea* sp.' appears to represent this species.

Spiriferina (?) carolinæ, sp. nov. (Pl. XXIII, figs. 19 *a*–20.)

Ventral valve semi-pyramidal in shape, dorsal valve almost flat. The hinge-line is straight, and represents the greatest width of the shell; the hinge-area is flat and vertical. The ventral beak is conical and blunt, and does not project above the hinge-area. The delthyrium is conical and apparently open. The hinge-area of the dorsal valve is narrow; the dorsal beak is broad and blunt, and projects but very slightly above the area.

The ventral valve has a faint, shallow, rapidly-widening, median sulcus, which extends from the anterior margin to near the apex, and on each side two very faint, shallow and broad, lateral sulci. Otherwise the surface is gently rounded, and the outline of the anterior margin is nearly semicircular. The dorsal valve, which is nearly flat, bears a very faint, broad, low, median fold bounded by scarcely perceptible lateral sulci.

The interior of the ventral valve (fig. 19 *a*) shows two thick and strong dental plates, which converge rapidly together and partly

[1] Catal. Ind. & Col. Exhibition (1886) p. 73, fig. 1.

fuse; they then become thinner and diverge again, the space between and in front of them bearing the adductor-scars. Immediately in front of their point of divergence a strong median septum is developed, which extends beyond the dental plates. The dorsal valve has a faint cardinal process with dental sockets on each side, and small, but well-marked, adductor and diductor scars. Ovarian pittings are well marked in both valves. The shell-structure is punctate, and the growth-lines become rather foliaceous towards the anterior margin.

Length=23 mm.; width=40 mm.; height of area of ventral valve=10 mm.

Locality and horizon.—It occurs in the Kaihiku Beds at Caroline Cutting, but seems to be scarce. I collected specimens, from which gutta-percha squeezes of the interior and exterior of both valves were made. Prof. Marshall possesses a specimen from the splintery argillites of Mount Potts (where it occurs in association with the Kaihiku fauna), which I recognized as the interior of a ventral valve of this species.

Remarks.—This brachiopod is peculiar as to shape, and as to form of the dental plates and septum, and I am unable to refer it definitely either to *Spiriferina* or to *Cyrtina*. The smoothness of its valves and the height of the hinge-area recall in some ways the very abnormal form *Cyrtina zitteli* Bittner from St. Cassian, but in that species the area of the ventral valve is enormously extended. The appearance of the dental plates in the casts at the back of the ventral beak, however, prevents its union with the genus *Cyrtina* as usually defined.

RETZIA SCHWAGERI Bittner. (Pl. XXIII, fig. 21.)

1890. 'Brachiopoden der Alpinen Trias' p. 21 & pl. xxxvi, figs. 1–4.
1899. 'Himalayan Trias Brach. & Lamellibranchs' p. 42 & pl. viii, figs. 1–3; p. 54 & pl. x, figs. 16–20.

Shell considerably longer than it is wide, beak prominent and pointed, lateral margins gently rounded, anterior margin rounded. The dorsal valve has a median rib, which is rather less prominent than the ribs on each side of it. There are seven rounded lateral ribs on each side of the median one; the last five of these are distinctly curved outwards, and all of them extend to the beak. The ventral valve has a median furrow no deeper than the next lateral furrows and seven lateral ribs.

Length=14 mm.; width=11 mm.

Locality and horizon.—Western slope of Mount Heslington, Nelson, in the *Halobia* Beds, where it is rather scarce. I have two or three casts and impressions, from one of which a gutta-percha squeeze of the outside of the shell was made. Carnic.

Remarks.—This shell resembles the Himalayan *R. schwageri* var. *asiatica* Bittner, but bears rather more numerous lateral ribs. *R. schwageri* is a species of wide vertical distribution, ranging from the Muschelkalk to the Dachsteinkalk in the Alps. In the Himalayas it occurs with *Halobiæ* of the group of *H. rugosa*.

Piroutet records three Alpine species of *Retzia* from the Trias of New Caledonia, of which *R.* aff. *superbescens* is the only one that resembles the present form.

MENTZELIA cf. AMPLA Bittner. (Pl. XXIII, fig. 9.)

1890. 'Brachiopoden der Alpinen Trias' p. 165 & pl. xli, figs. 10–11.

Ventral valve inflated, the dorsal rather less so, area triangular, rather high, less than the width of the shell, the ventral beak somewhat bent over it. The ventral valve has a broad and shallow rounded sulcus, which does not continue to the apex. The dorsal valve bears a rather broad, rounded, triangular fold, which does not reach the beak and is bordered on both sides by steep slopes. In the ventral beak there is a sharp median septum with sharp dental plates on each side of it. The shell-structure is fibrous, and at the same time faintly punctate.

Length = 31 mm.; width = 42 mm.; thickness = 20 mm.

Locality and horizon.—I collected a single specimen in pebbly sandstones, with *Arcestes* cf. *rhæticus* and *Hectoria bisulcata*, several hundred feet above the *Pseudomonotis-ochotica* Beds, north of Albatross Point, Kawhia. The wings of this specimen are damaged, and the ventral beak is slightly eroded. Rhætic.

Remarks.—This smooth *Mentzelia* seems to agree closely with the above-named species, which Bittner thinks may be a variant of the Muschelkalk form *M. mentzeli*. In the Alps *M. ampla* occurs at a horizon corresponding to that of the St. Cassian Beds; while the typical *M. mentzeli* is predominantly a Muschelkalk form, but has been found also in the Carnic of Spiti in the Himalayas.

MENTZELIA KAWHIANA, sp. nov. (Pl. XXIII, figs. 10 *a* & 10 *b*.)

Shell rather wider than long, the anterior margin gently rounded. The ventral valve is somewhat swollen and arched, the beak tapering gradually, the dorsal valve is almost flat, and the margin of the valves lies nearly in one plane. The area is less than the width of the shell, and seems to have been rather high. The ventral valve has a shallow, rounded, rather broad, median sulcus, with about seven very faint and narrow, lateral, rounded ribs on each side of it: these do not continue to the beak, and are absent from the lateral portions of the shell. The dorsal valve bears a very faint, flattened, triangular, median fold and about seven very faint, narrow ribs on each side of it which do not reach the beak. The lateral portions of the shell towards the hinge-area are smooth.

Length = 25 mm.; width = 31 mm.

Locality and horizon.—I collected a single specimen not far from the last-described form in the *Arcestes* and *Hectoria* Beds, in the cliff-section south of Kawhia Harbour. Rhætic.

Remarks.—The shell-structure is fibrous and faintly punctate. This form rather closely resembles *M. palæotypus* Loretz, from the Alpine Muschelkalk, but has fewer radial ribs, a weaker dorsal fold and ventral sulcus, a more prominent beak, and a less inflated shell.

MENTZELIOPSIS, gen. nov. (Pl. XXIII, figs. 11–18.)

Shell thin, the growth-lines being visible on the inner surface. Beak of the ventral valve prominent, arched, and tapering rapidly. Hinge-line straight and rather shorter than the greatest width of the shell. Area triangular, concave, striated parallel to the margin, with an open triangular delthyrium. The hinge-teeth situated on each side of the delthyrium are somewhat prominent, and are supported by two sharp plates. A sharp and prominent median septum extends for nearly half the length of the ventral valve. The dorsal valve is flatter than the ventral. Dental sockets are present, and between them is a short, blunt, cardinal process. An obscure cardinal area is present in the dorsal valve, and there is a faint median dorsal septum. Muscular and vascular impressions are obscure. The outer surface of both valves bears prominent, fairly-equidistant, more or less foliaceous growth-lamellæ, and is covered with tubular spines measuring up to 3 or 4 mm. in length. The spines generally occur on the surface between the growth-lamellæ, but occasionally the latter are prolonged into spines. There is a more or less prominent dorsal median fold and ventral sinus, and fainter lateral ridges. Owing to the feeble articulation the valves are generally found separated.

A specimen which I ground down showed the spiralia directly connected with the crural processes, and two discrete jugal processes, a condition which obtains in the true Spirifers and in *Mentzelia*.

The following points show that the brachiopod is really a thin-shelled spiny *Mentzelia* :—

(*a*) The outline, area, and sulcation are that of *Mentzelia*.

(*b*) There is a strong ventral median septum with sharp dental plates on each side of it, well seen in every cast of the ventral beak.

(*c*) The only specimen that I had available to grind down showed that the junction of spirals and crura was simple, and the juga apparently discrete.

(*d*) The shell-structure is fibrous and silky, but on the only specimen that I have which shows any of the test no punctation could be seen; if present, it is very faint.

The founding of a new genus or subgenus for this shell requires some explanation. *Mentzelia* is generally a perfectly-smooth shell, but Bittner mentions the fact that von Schauroth found a specimen of *Mentzelia mentzeli* in the German Muschelkalk with a covering of hair-like spines. The New Zealand form, at least two species of which seem to occur, has the surface of both valves covered with comparatively long tubular spines. It bears a similar relation to *Mentzelia* as *Acanthothyris* does to *Rhynchonella*. I adopt the commoner species *M. spinosa* as the genotype.

Locality and horizon.—It seems to be confined to the Kaihiku Beds, Ladino-Carnic. The only true *Mentzeliæ* that I found in New Zealand were in the Rhætic. On looking over the material that I collected at Mount Heslington, in the Nelson district, I find some dorsal valves of a small spiny brachiopod,

which, though scarcely adequate for a specific description, appear to represent a dwarfed species of *Mentzeliopsis*. These occur in the Carnic with *Halobia zitteli* var. *zealandica*.

Mentzeliopsis spinosa, sp. nov. (Pl. XXIII, figs. 11–16.)

The shell is slightly wider than it is long; the area is rather concave, less than the greatest width of the shell, and striated parallel to the hinge-margin. The ventral valve is inflated and arched; the beak is prominent, tapers rapidly, and is rather bent over the area. The delthyrium is triangular and deeply sunken. The ventral valve has a feeble, wide, median sulcus and very feeble lateral dorsal folds.

The dorsal valve is much flatter than the ventral, and has a broad, rapidly-widening, triangular, slightly-raised fold. on each side of which are about five very feeble, narrow, lateral folds. The growth-lines are rather widely spaced and foliaceous, and are sometimes produced into tubular spines. The latter also occupy the spaces between the growth-lines, but are not very closely set. They attain a length of 3 or 4 millimetres.

A ventral valve measures 19 mm. in length and 32 mm. in width; another 25 mm. and 30 mm.; two dorsal valves are respectively 20 mm. long and 31 mm. wide, and 20 mm. long and 26 mm. wide.

Locality and horizon.—Kaihiku Beds at Caroline Cutting; Kaihiku Gorge; Eighty-Eight Valley, in the Nelson district; and other localities, where it is common. Ladino-Carnic.

Remarks.—I collected most of my specimens at Caroline Cutting, and made several gutta-percha squeezes of the exterior and interior surfaces of both valves.

Mentzeliopsis horrida, sp. nov. (Pl. XXIII, figs. 17 & 18.)

Valves rather inflated, both about equally so. Shell slightly wider than it is long; the ventral beak is broad, and tapers slowly. The ventral valve has a broad, shallow, median sulcus which reaches to the beak, and on each side of it about six rather faint, but well-marked, rounded, narrow lateral folds, which also reach nearly to the beak.

The dorsal valve bears a rounded, triangular, rapidly-widening, median fold, with a smaller fold passing down the middle of it, and four or five rather faint, lateral, rounded folds, all of which reach to the beak. The spines are short, and small and closely set. Growth-ridges are widely set and well marked, but not foliaceous.

Length = 22 mm.; width = 26 mm.

Locality and horizon.—Kaihiku Beds at Caroline Cutting and elsewhere, where it seems to be scarce; but I collected casts from which gutta-percha squeezes of both valves were made. Ladino-Carnic.

Remarks. This form differs from *M. spinosa* in having a broader beak and a more inflated dorsal valve. The ribs are better marked and reach to the beak, and the spines are more numerous, smaller, and more closely set.

Spirigera wreyi Zittel. (Pl. XXV, figs. 6 *a* & 6 *b*.)

1864. 'Paläontologie von Neu-Seeland' p. 28 & pl. viii, figs. 3 *a*–3 *d*.

Zittel, when he described it, had only casts of this species, which Hochstetter collected in the Nelson district. I therefore take the opportunity of describing and illustrating a fine uncrushed testiferous example, which I found in a pebbly felspathic grit on the western slope of Mount Heslington. It is rather wider than long, the ventral valve is rather inflated, the dorsal less so. The ventral beak is comparatively small; the area is narrow and faintly striate parallel to the hinge-margin; the delthyrium is triangular and deeply sunken, and only slightly hidden by the dorsal beak. The apex is perforated by a pedicular foramen of moderate size. The ventral valve has a broad, shallow, median sulcus which dies away about halfway to the beak, and two faint lateral sulci which only appear near the anterior lateral margins. The dorsal valve bears near its anterior margin a broad median fold, which is bordered by steep slopes. It measures 28 mm. in length, 31 mm. in width, and 16 mm. in thickness. The growth-lines are well marked.

Locality and horizon.—This is a common Carnic fossil in New Zealand: it occurs at Mount Heslington and in the Wairoa Gorge; in the Hokonui Hills; at Nugget Point and other places in the South Island. It is also reported to occur in New Caledonia.

Remarks.—Zittel mentions the large cardinal process, and Bittner remarks upon the resemblance of this shell to the Alpine Rhætic *Spirigera oxycolpos.*

I have employed the generic name *Spirigera* (A. d'Orbigny, 1847) in preference to *Athyris* (McCoy, 1844) for the Triassic forms of this group, in conformity with the writings of Zittel, Bittner, Diener, and others, by whom it is used so largely. The name *Spirigera* seems to be coming into use to designate the Mesozoic Athyrids.

Spirigera kaihikuana, sp. nov. (Pl. XXV, fig. 5.)

Shell rather inflated, the ventral valve slightly more than the dorsal. Outline elongate-oval or subtriangular, often widening out towards the anterior margin, which is gently rounded. The ventral beak is prominent, and tapers gradually. The delthyrial cavity is more or less entirely concealed by the dorsal beak. The foramen was wide and remained open during life, as the casts are always attached to the interior of the cavity by rock which filled up the foraminal passage: this, in some examples, is extended forward, and encroaches on the delthyrium.

There is a faint broad fold on the anterior part of the dorsal valve, and a very faint corresponding median depression on the ventral valve: consequently, the junction of the valves lies almost in one plane. The ventral apical region is much thickened at the sides with shelly material, but a passage for the pedicle-muscle always remains.

One specimen measures 41 mm. in length and 31 mm. in width; another, of more triangular outline, is 46 mm. long and 52 mm. wide.

Locality and horizon.—It is confined to the Kaihiku Beds, and casts are very common at Caroline Cutting, Kaihiku Gorge, and other localities. I have a few specimens with the shell preserved, as also a large number of casts. Ladino-Carnic.

Remarks.—This species belongs to the group of *Spirigera wreyi*, but is larger, has a more oval or elongate outline, the delthyrial region is more hidden by the dorsal beak, the pedicle-passage remained wide and open, the fold and sinus are much feebler, and the shell-structure is more coarsely fibrous. It occurs on a lower horizon than *Sp. wreyi*, which is a Carnic fossil.

SPIRIGERA MANZAVINIOIDES, sp. nov. (Pl. XXV, figs. 7 *a* & 7 *b*.)

Shell wider than long; valves only slightly convex near the beaks, the ventral rather more so than the dorsal, becoming flattened towards the margins. Near the anterior margin there is a broad but feeble ventral sulcus, and a low and broad rounded dorsal ridge bounded by wide, feebly-marked, lateral sulci. The area is small, and less than the width of the shell; the beak is very small and pointed, and projects but very slightly over the hinge-line. The pedicle-passage is minute. The growth-interruptions are prominent, foliaceous, irregular, and widely spaced, and the interspaces are marked with very faint, regular, parallel, concentric striæ. The shell-structure is coarsely fibrous, the fibres directed towards the median line. A typical, somewhat flattened, specimen is 30 mm. long and 40 mm. wide.

The internal structure is as follows: it has a thickened ventral hinge-region and a large cardinal process, beneath which a cavity projects backwards into the beak region, and is divided by a short, blunt, median septum. The end of the cardinal process carries a triangular depression, and there are prominent ventral hinge-teeth supported by plates.

Locality and horizon.—I collected six or seven specimens in dark shales along with *Halobia zitteli* var. *zealandica* in Bed *e*, Otamita, Hokonui Hills. They have the shell preserved, but are somewhat flattened or laterally distorted. Carnic.

Remarks.—This shell belongs to the group of *Spirigera oxycolpos* Emmrich, of the Rhætic Kœssen Beds, the latest and largest of the European Spirigerids; but it differs in being much flatter, whereas the full-grown *Sp. oxycolpos* is a swollen and rounded shell. It comes very near in shape and outline to *Sp. manzavinii* Bittner[1] of the Upper Trias of Balia in Asia Minor, a form which (as Bittner remarks) bears comparison with the New Zealand species *Sp. wreyi*. In *Sp. manzavinii*, however, the foramen is large, whereas in the present form it is quite minute.

[1] Bibliography, 6, xli, p. 107 & pl. i, figs. 9–11.

Spirigera eurycolpos Bittner,[1] of the Alpine Dachsteinkalk, also belongs to this group, but differs from the present form in shell-outline and other details. The internal structure is essentially similar to that of *Sp. oxycolpos*, which Zugmayer has described in detail, a structure which exists in a more exaggerated form in the group next to be described.

I have very strong reasons to think that the New Zealand Trias, if thoroughly searched, would yield more and different forms of the group of *Spirigeræ*, to which *Sp. wreyi*, *Sp. kaihikuana*, and *Sp. manzavinioides* belong. The New Zealand Geological Survey possesses another such form, and I have fragments of others; but the rather doubtful locality-record of the former, as also the poor condition of my material, makes it unadvisable to found further new species at present.

HECTORIA, gen. nov. (Pl. XXV, figs, 1 *a*–4 *b*.)

The hinge-line slopes very slightly away from the beaks, and represents the greatest, or nearly the greatest, width of the shell. The ventral area extends for nearly the whole length of the hinge-line: it is narrow, but conspicuous, and has faint parallel striations; the area of the dorsal valve is nearly obsolete. The ventral beak projects but very slightly above the hinge-line; the dorsal beak is rather less prominent. The valves are almost equally convex; the ventral sometimes slightly more so than the dorsal. Both valves have a more or less pronounced, median, rapidly-widening sinus, bounded on each side by rounded lateral folds which diverge from the beak and pass to the anterior margin, where they meet similar folds of the opposite valve. The junction of the valves lies almost in one plane, or is very slightly sinuous. The shell-structure is silky and fibrous, the fibres being mostly directed towards the median line. In a cast that I collected in Carnic beds near Gore, in the Hokonui district, the beak has been pierced by a narrow and long arched tubular foramen, but in others, and especially in the larger and more fully grown specimens, the foramen is filled up and obliterated by the shelly thickening of the beak. The delthyrium is triangular and sunken, and in the larger specimens at least is closed.

Fig. 4.—*Specimen of* Hectoria *sp. from Carnic shales at Otamita, partly ground down.*

a = Dental sockets.
b = Cardinal process of the dorsal valve.
c = The recurving of the primary lamellæ.
d = The medio-laterally directed spiralia.

[1] Bibliography, 4, p. 273 & pl. xxix, figs. 7–13.

The following account of the internal structure is based chiefly on large specimens of *Hectoria tumida*, from the Rhætic of Benmore Cutting, where fine moulds and casts occur, from which I obtained gutta-percha impressions. The interior of the ventral valve is considerably thickened posteriorly by deposition of shelly matter; the hinge-teeth are prominent, are supported by short dental plates, and there is a short median septum.

In the dorsal valve the hinge-region is still more thickened; the cardinal process is very large and prominent, and consists of a blunt tongue-shaped mass of shell, which projects backwards beneath the delthyrial region of the ventral valve. The cardinal process has a shallow depression on its surface. In front of the cardinal process a deepened cavity projects backwards beneath it,

Fig. 5.—*Gutta-percha squeezes of interior of apices of valves of* Hectoria tumida, *gen. et sp. nov. (Natural size.) Rhætic. Benmore Cutting.*

a = Dorsal valve, showing the large tongue-like cardinal process with the hollowed-out space in front of and below it divided by a median septum. Slight dental sockets occur on each side of the cardinal process.

b = Ventral valve, showing the concave slightly-striated area, the small hinge-teeth and plates supporting them, and the small median septum.

and is divided by a rather high, blunt, median septum which separates the two adductor-scars. On each side of the cardinal process is a fairly-deep dental socket. The ovarian pittings, vascular impressions, and muscle-scars are well marked in both valves, the diductor-scars of the ventral valve being flabellate. The spiral cones are laterally directed. The arrangement of the juga and junction of the spiralia with the crura could not easily be seen; but, on grinding down a specimen from the Carnic shales at Otamita, I concluded that it was similar to that which obtains in other Spirigerids.

This genus comprises a well-defined group of specialized bisulcate Spirigerids, which shows close relationship to *Sp. oxycolpos* of the Alpine Rhætic in the structure of the cardinal process and the deepened pit beneath it. They differ, however, in features sufficiently marked to justify their attribution to a new genus or subgenus, such as the equal convexity and equal median sulcation in both valves, the greater internal posterior thickening of the valves, and the relatively-larger size of the cardinal process.

Locality and horizon.—Two species appear to occur in the Trias, and one in the Jurassic, of New Zealand. They are rather scarce in the Carnic of the Hokonui district; but they occur in great abundance in some beds of Rhætic age, and a single rather dwarfed form survives into the Jurassic.

Remarks.—Hector proposed the generic name *Clavigera* for this group, in a paper read before the Wellington Philosophical Society in 1878. An abstract of this paper was published the following year, but it never appeared in full. Some plates which he caused to be printed about that time have recently been issued with a palæontological bulletin already mentioned.[1] Pl. i is occupied by illustrations of the genus *Clavigera*. Some years ago Mr. McKay collated these plates, and labelled the species so far as he could from memory: he gave the species on pl. i as follows: *Clavigera bisulcata*, *Cl. cuneiformis*, *Cl. gracilis*, *Cl. tumida*, and *Cl.* 'sp. innom.' I have adopted the specific names *bisulcata*, *tumida*, and *cuneiformis* for the forms for which Hector apparently intended them—the last name referring to the Jurassic shell. *Clavigera gracilis* is a cast from Benmore Cutting, apparently identical with *Cl. tumida*. Hector gave drawings of *Cl. cuneiformis* and of a cast of *Cl. tumida*, but without any specific names, in a work issued in 1886.[2] For reasons already stated, I considered it advisable to discard Hector's name *Clavigera* and to institute that of *Hectoria* instead.

HECTORIA BISULCATA, sp. nov. (Pl. XXV, figs. 1 *a* & 1 *b*.)

Shell rather wider than long, moderately inflated, the valves almost equally convex. The hinge-line is nearly straight, and represents the greatest width of the shell. The area is narrow and faintly striate parallel to the margin, and the ventral beak projects slightly above the area. The delthyrium is triangular and insunken. The growth-lines show that the outline of the young shell was rather strongly alate; but towards maturity it becomes less so, and is more or less produced anteriorly. The outline maintains the same width at the sides for some distance from the hinge-line, and then narrows to the anterior margin, which is gently rounded. In both valves two raised rounded ridges diverge from the beaks, and proceed towards the anterior margin meeting the similar ridges of the opposite valve. They enclose a shallow,

[1] Bibliography, 47.
[2] Catal. Ind. & Col. Exhib. (1886) p. 72, figs. 2 & 3.

rapidly-widening, triangular sulcus; but towards the anterior margin both ridges and sulcus become weaker, and merge into the rounded surface of the shell. The junction of the shell is but slightly sinuous.

The type-specimen is 51 mm. long, 63 mm. wide, and the two valves are 23 mm. deep.

Locality and horizon.—Casts apparently of this species occur in Carnic and Noric strata at Otamita, Hokonui Hills. At Nugget Point it is extremely abundant, together with *Spiriferina diomedea*, at the southern end of Roaring Bay, in a bed of very hard pebbly sandstone of Rhætic age, which here closes the Triassic sequence. It is less common at Kawhia, where it occurs sporadically through a very thick series of grey sandy Rhætic deposits overlying the Noric *Pseudomonotis* shales. I obtained one very fine example there and several less perfect ones, also several specimens at Nugget Point. The New Zealand Geological Survey possesses a specimen from blue sandstones and chert at the main branch of Taylor's Creek, on the south side of the Hokonui Hills, in beds apparently of Rhætic age.

Hectoria tumida, sp. nov. (Pl. XXV, fig. 2.)

Shell very slightly wider than long; valves inflated, the ventral often rather more so than the dorsal. The hinge-line slopes gently from the beaks, and represents rather less than the greatest width of the shell; the area is concave, and striated parallel to the margin. The ventral beak is broad, and projects slightly above the hinge-area. The delthyrium is triangular and insunken, and closed internally by shelly matter; it is partly concealed by the dorsal beak. The outline is gently rounded at the sides, but is somewhat prolonged and rounded anteriorly. Rounded ridges diverge in both valves from the beak, and extend to the anterior lateral margins; but in this species they become somewhat indistinct, and tend to merge into the swollen and rounded outline of the shell, and on the dorsal valve they form a more or less flattened or gently rounded, raised, median, triangular fold rather than a sulcus. The growth-lines are well marked towards the anterior margin.

A typical specimen is 60 mm. long and 63 mm. wide.

Locality and horizon.—Benmore Cutting, on the south side of the Hokonui Hills, in a coarse, decomposed, pebbly, felspathic sandstone. Many casts of this large shell occur here. I collected and brought home several internal casts, and a mould from which I was able to obtain a gutta-percha impression of the ventral beak and area and dorsal valve; but the surface of the shell is damaged and pitted by the quartz-grains in the rock. The description of the internal structure of the hinge-region given in the diagnosis of the genus is based on moulds of the separated ventral and dorsal valves, which I obtained in this locality and brought home with me. Rhætic.

Remarks.—This is a distinctive form, and seems to occur in high Rhætic beds. It differs from *H. bisulcata* in its larger size

[To face p. 237.]

VI. Synopsis of the Divisions and Fossils of the New Zealand Trias.

	UPPER TRIAS.											MIDDLE TRIAS?	
	Otapiri.					Wairoa.				Oreti.		Kaihiku.	
	Rhætic.	Noric.			Carnic.							Ladino-Carnic.	
	Spiriferina diomedea and *Hectoria tumida.*	*Pseudomonotis ochotica.*	*Pseudomonotis richmondiana.*		*Halobia* sp.	*Halobia zitteli* var. *zealandica* and *Halobia* cf. *austriaca.*	*Mytilus (?) problematicus.*		*Myophoria nuggetensis.*			*Daonella indica* and *Spiriferina fragilis.*	Affinities and Occurrence outside New Zealand.
Cephalopoda.													
Orthoceras sp.	...	...	...	...	...	+							
Grypoceras cf. *mesodiscum* Hauer	...	...	...	...	...	+	...	...	...	...	...	...	Alps.
Clydonautilus cf. *spirolobus* Dittmar	...	...	...	...	...	+	...	...	...	...	...	...	Alps.
Arcestes sp.	...	...	...	...	...	+							
Arcestes cf. *rhæticus* Clark	+	...	...	...	...	...	...	...	...	...	...	...	Alps (Rhætic).
Cladiscites sp.	...	...	...	...	...	+	?						
Pinacoceras sp.	...	...	...	+	?	?							
Discophyllites cf. *ebneri* Mojsisovics	...	...	...	...	...	+	?	..	...	...	...	...	Himalayas, New Caledonia (?).
Aulacoceras sp.	...	...	...	+	?								
Gasteropoda.													
Patella (?) nelsonensis, sp. nov.	...	...	...	...	...	...	...	...	...	...	...	+	
Pleurotomaria (Sisenna) hectori, sp. nov.	...	?	...	...	...	+							
Pleurotomaria hokonuiensis, sp. nov.	...	...	...	...	...	+							
Coronaria spectabilis, sp. nov.	...	...	...	...	...	+							
Bourguetia (?) arata, sp. nov.	..	...	...	...	...	+							
Trochus (Tectus ?) marshalli, sp. nov.	...	...	...	...	...	+							
Scaphopoda.													
Dentalium sp.	...	...	...	...	...	+							
Pteropoda (?).													
Conularia sp.	...	...	+	...	...	+	+						
Lamellibranchiata.													
Cardiomorpha (?) nuggetensis, sp. nov.	...	...	...	...	?	?							
Palæoneilo otamitensis, sp. nov.	...	...	...	...	...	+							
Palæoneilo cf. *præacuta* Klipstein	...	...	...	...	...	+							
Leda semicrenulata, sp. nov.	...	...	...	...	...	+							
Macrodon cf. *curionii* Bittner	...	...	...	...	...	+							
Pseudomonotis ochotica Teller	...	+	...	...	...	...	...	...	...	...	...	...	Himalayas, Malay Islands, Arctic Siberia, Japan, etc. (Noric).
Do. do. varieties	...	+	...	...	...	...	...	...	...	...	...	...	
Pseudomonotis richmondiana Zittel	...	...	+	...	...	...	...	...	...	...	...	...	New Caledonia (Noric).
Do. do. varieties	...	...	+	...	...	...	...	...	...	...	...	...	
Monotis salinaria Bronn	...	...	...	?	...	...	...	...	...	...	...	...	Alps, Pamirs, Afghanistan, Himalayas, Malay Islands (Carnic and Noric).
Do. do. var. *intermedia*, nov.	...	...	...	?	...	...	...	...	...	...	...	...	
Do. do. var. [illegible], nov.				?									

Daonella indica Bittner	...	...	...	...	...	...	...	...	...	...	...	+	Himalayas, Malay Islands.
Halobia zitteli var. *zealandica*, nov.	...	...	...	...	...	+	...	...	...	...	...	...	Closely related form in Spitsbergen, Bear Island, and New Caledonia.
Halobia hochstetteri Mojsisovics	...	...	...	...	...	+	...	...	...	...	...	...	New Caledonia (?).
Halobia cf. *austriaca* Mojsisovics	...	...	...	...	...	+	...	...	...	...	...	...	Alps, New Caledonia (?).
Halobia spp.	...	...	...	...	+	+							
Mytilus (?) problematicus Zittel	...	...	...	...	...	...	+	...	...	...	...	...	New Caledonia.
Mytilus (?) mirabilis, sp. nov.	...	..	...	...	...	...	+						
Hokonuia limæformis, gen. et sp. nov.	...	...	...	...	...	+							
Hokonuia rotundata, sp. nov.	...	..	...	...	...	+	+						
Hokonuia spp.	..	..	...	...	...	+	+						
Pinna sp.	...	..	...	...	...	?	?						
Pecten sp.	..	.	..	...	...	+							
Limatula cf. *pichleri* Bittner	...	...	...	...	...	+	...	...	...	...	...	...	Alps.
Cassianella sp.	...	.	...	...	...	+							
Anodontophora angulata, sp. nov.	...	...	...	...	...	+							
Anodontophora ovalis, sp. nov.	..	...	...	...	...	+	...	...	...	...	...	...	Allied to Himalayan forms.
Anodontophora edmondiiformis, sp. nov.	.	.	...	...	...	+	...	...	..	...	...	...	
Megalodon globularis, sp. nov.		..	...	...	..	...	+	+					
Pseudoplacunopsis placentoides, sp. nov.	...	...	...	...	...	+							
Myophoria nuggetensis, sp. nov.	...	.	...	...	...	...	...	...	+				
Myophoria otamitensis, sp. nov.	?	...	...	?	+	+							
Myophoria heslingtonensis, sp. nov.	...	...	...	.	...	+							
Palæocardita quadrata, sp. nov.	..	...	...	...	...	+	...	...	...	...	...	...	Allied to forms in St. Cassian Beds.
Pleurophorus zealandicus, sp. nov.	..	...	...		..	+							
Anisocardia (?) parvula, sp. nov.	...	...	...	...	...	+							
Brachiopoda.													
Halorella zealandica, sp. nov.	...	...	...	...	...	..	..	...	...	?	?	+	
Halorella sp.	...	...	..	...	...	?	?	...	...	...	...	...	Related to the Alpine form *H. pedata*.
Dielasma cf. *himalayana* Bittner	...	...	...	...	...	..	...	...	...	...	?	+	Himalayas.
Dielasma zealandica, sp. nov.	..	...	...	...	...	...	...	...	...	...	...	+	
Cœnothyris (?) sp.	.	...	+										
'*Terebratula*' *pachydentata*, sp. nov.	...	...		..	...	+							
'*Terebratula*' cf. *hungarica* Bittner	..			..	...	+							
Spiriferina fragilis Schlotheim		.	..	...	...	...	...	...	...	...	..	+	European Muschelkalk, Alps, Himalayas, New Caledonia
Spiriferina kaihikuana, sp. nov.			..	.	...	..	...	...	...	...	...	+	
Spiriferina gypaëtus, sp. nov.	.	.	.	+									
Spiriferina acutissima, sp. nov.	..			+	+	+							
Spiriferina diomedea, sp. nov.	+												
Spiriferina nelsonensis, sp. nov.	..	...	.	.	.	+							
Spiriferina cf. *austriaca* Suess		..	...	...	...	...	..	...	...	?	?	...	Related to Alpine Rhætic form.
Spiriferina otamitensis, sp. nov.	.	.		...		+							
Spiriferina suessi var. *australis*, nov.	...	...			+	+	..	...	...	...	...	...	Related to Alpine Rhætic form.
Spiriferina (?) carolinæ, sp. nov.	..	.	...	...	...	...	...	..	...	...	...	+	
Retzia schwageri Bittner	...	...	..	...	?	+	..	..	...	...	...	...	Alps, Himalayas.
Mentzelia cf. *ampla* Bittner	+	..	.	...	...	...	...	...	...	...	...	..	Related to Alpine and Himalayan Muschelkalk and Carnic forms.
Mentzelia kawhiana, sp. nov.	+	.	...	..	...	...	..	...	...	...	...	...	
Mentzeliopsis spinosa, gen. et sp. nov.	...	..	...	...	...	...	...	..	...	...	...	+	
Mentzeliopsis horrida, sp. nov.	...	...	..	...	...	..	...	...	...	...	...	+	
Spirigera wreyi Zittel	...	...	...	...	...	+	..	.	...	...	..	...	New Caledonia (?).
Spirigera kaihikuana, sp. nov.	...	...	...	...	...	.	...	..	...	...	...	+	
Spirigera manzavinioides, sp. nov.	...	...	...	...	...	+	...	..	...	...	...	...	Allied to form in the Trias of Asia Minor.
Hectoria bisulcata, gen. et sp. nov.	+	...	...	?	?	?	...	...	...	...	...	...	Related to *Spirigera oxycolpos* of the Alpine Rhætic.
Hectoria tumida, sp. nov.	+	...	...	..	...	...	...	...	...	...	...	...	
Hectoria cuneiformis, sp. nov. (Jurassic.)													
Echinodermata.													
Entrochus undatus Bather	...		...	..	...	...	...	...	...	...	...	+	
Entrochus ternio Bather	...	...	...	...	...	...	...	...	...	...	...	+	
Isocrinus trechmanni Bather	...	...	..	.	...	...	..	..	...	...	...	+	
Plantæ.													
Thinnfeldia cf. *odontopteroides* Morris	...	...	...	...	...	+							
Vertebrata.													
Ichthyosaurus (?) sp.	...	...	...	...	+	+	...	...	...	...	...	+	

and more inflated shell, its relatively narrower hinge-line, and much less clearly-marked folds and sulcus. In its general rounded outline and swollen surface it somewhat recalls full-grown specimens of the Alpine *Spirigera oxycolpos*.

HECTORIA CUNEIFORMIS, sp. nov. (Pl. XXV, figs. 4 *a* & 4 *b*.)

Valves about equally convex, compressed, and but slightly inflated. The junction of the valves is nearly straight. The hinge-margin slopes very gently away from the beak, and represents the greatest width of the shell. The ventral beak is very small, and projects but slightly above the hinge-margin; the ventral area is extremely narrow. In front of the hinge-line the lateral margins converge together rather rapidly, and the anterior margin is strongly hollowed out between the ridges. The median sulcus and the rounded ridges on each side of it are well marked in both valves; they continue in full strength from the beak to the anterior margin. Ridges of growth are rounded and fairly prominent, and the structure of the shell is coarsely fibrous.

The type-specimen, from Taylor's Creek, is 25 mm. long, 37 mm. wide, and 11 mm. thick.

Locality and horizon.—A fine specimen in the New Zealand Geological Survey Collection was obtained in the lowest part of the lower Ammonite Bed at Taylor's Creek, in the Hokonui Hills. Prof. P. Marshall lent me a fragment of a valve that he collected at Totara Point, in the harbour of Kawhia. I am at present uncertain about the exact horizon of the Jurassic at Totara Point; but I think, from an examination of the associated fossils, that it is Bajocian.

Remarks.—This form is smaller than *H. bisulcata*, the sulcus and ridges are better marked, and the beaks relatively smaller. It is a dwarfed Jurassic survival of an essentially Upper Triassic group.

VII. RELATION OF THE NEW ZEALAND TRIAS TO THAT OF NEW CALEDONIA AND THE MALAY ARCHIPELAGO.

New Caledonia lies on the north-westerly continuation of the Australian festoon or submarine ridge which connects the Auckland Peninsula with Norfolk Island and the Malay region.

On the south-western side of New Caledonia the Trias shows a close agreement with that of New Zealand. The points of similarity and difference seem to be as follows:—

(*a*) At the base occurs a thick detrital series devoid of fossils. Piroutet supposes this to represent probably the Permian and the lower divisions of the Trias, and it evidently corresponds with the Kaihiku Series below the lowest fossiliferous horizon in New Zealand.

(*b*) Above this comes a series of shales, greywackes, tuffs, andesitic breccias, and conglomerates, which represent the

Ladinic, Carnic, and Noric horizons, and pass conformably upwards into the Lias.

(*c*) Piroutet regards the lowest fossiliferous beds, which contain *Halobia zitteli*, as of Upper Ladinic age. I can find no mention of the occurrence of any equivalent in New Caledonia of the Kaihiku fossiliferous beds with *Daonella indica*, which form a lower horizon than the *Halobia-zitteli* Bed in New Zealand. *Spiriferina fragilis*, however, figures in Piroutet's list of fossils, and so some members or survivals of the Muschelkalk fauna seem to be present. I prefer to regard *Halobia zitteli* as a Carnic fossil and the bed below it as Ladino-Carnic.

(*d*) The Carnic Series in New Caledonia has the beds with *Mytilus problematicus* as its base, and includes among its fossils *Halobia superba*, *H. austriaca*, several indeterminate species of *Arcestes*, *Discophyllites*, *Spirigera*, *Spiriferina*, etc.

(*e*) The Noric attains a thickness of at least 4920 feet, and contains *Pseudomonotis richmondiana* in great abundance. There is no record yet of *Ps. ochotica* or *Monotis salinaria* in New Caledonia.

(*f*) No mention is made of any definite Rhætic fauna, nor can any reference to the bisulcate Spirigerids of the *Hectoria* group be found. Piroutet, however, records fossils which present affinities with those of the Alpine Dachstein in his lists.

(*g*) The *Mytilus-problematicus* Beds are said to be transgressive, and to begin in the coastal region with a conspicuous conglomerate, which rests upon the trachytic tuffs of the middle portion of the underlying series. The *Pseudomonotis* Beds are again transgressive, and rest upon beds increasingly older as they extend westwards.

The presence in New Zealand of thick and coarse conglomerates at various horizons, together with the local absence of the Noric *Pseudomonotis* Beds, points to local transgression and retrogression. This is notably the case at Nugget Point, where a thick coarse conglomerate appears rather low in the Carnic, and where the *Pseudomonotis* Beds are entirely wanting. The Trias in New Zealand, however, is too much disturbed, and the outcrops are too discontinuous to enable one to make definite assertions as to the extent or direction of such transgressions.

The Triassic deposits in the eastern part of the Malay Archipelago belong, with one exception, to the Upper Trias. The exception is that of a piece of rock containing a Ceratitic ammonite of the genus *Dinarites*, which was ejected by a mud-volcano on the southern coast of Timor. Upper Trias has been found on seven distinct islands spread over the whole East Indian Archipelago. The beds discovered by Volz in Sumatra, and those in Borneo described by Vogel, are also of Upper Triassic age.

The faunal transgression which began over a wide area of the Malay Archipelago at the end of the Middle Trias, or the beginning of the Upper Trias, extended also to the regions now occupied by New Caledonia and New Zealand.

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EXPLANATION OF PLATES XVII–XXV.

Plate XVII.

Fig. 1. *Arcestes* cf. *rhæticus* W. B. Clark. Rhætic: north-east of Albatross Point, Kawhia. Two-thirds of the natural size. Marshall Coll. (P. 182.)

2. *Cladiscites* sp. Carnic; Mount Heslington, Nelson. Natural size. N.Z. Geol. Surv. Collection. (P. 183.)

3. *Clydonautilus (Proclydonautilus)* cf. *spirolobus* Dittmar. Carnic; Nugget Point. One-third of the natural size. N.Z. Geol. Surv. Coll. (P. 182.)

4. *Aulacoceras* sp. Noric (?): Oreti Cutting, Hokonui Hills. Two-thirds of the natural size. N.Z. Geol. Surv. Coll. (P. 184.)

5. *Aulacoceras* cf. *sulcatum* Hauer. Natural size. Carnic (?): Eighty-Eight Valley, Nelson. N.Z. Geol. Surv. Coll. Gutta-percha squeeze. (P. 184.)

6. *Orthoceras* cf. *triadicum* Mojsisovics. Carnic; Otamita, Hokonui Hills. Natural size. Trechmann Coll. (P. 181.)

7. *Discophyllites* cf. *ebneri* Mojsisovics. Carnic; Mount Heslington, Nelson. One-third of the natural size. Trechmann Coll. (P. 184.)

Plate XVIII.

Fig. 1. *Conularia* cf. *lævigata* Morris. Carnic; Otamita, Hokonui Hills. Natural size. Trechmann Coll. (P. 189.)

2. *Dentalium* sp. Carnic; Otamita, Hokonui Hills. Natural size. Trechmann Coll. (P. 188.)

3. *Bourguetia (?) arata*, sp. nov. Carnic; Mount Heslington, Nelson. Natural size. Gutta-percha squeeze. N.Z. Geol. Surv. Coll. (P. 188.)

4. *Coronaria spectabilis*, sp. nov. Carnic; Mount Heslington, Nelson. Natural size. Gutta-percha squeeze. N.Z. Geol. Surv. Coll. (P. 187.)

Figs. 5 *a*–5 *c*. *Pleurotomaria (Sisenna) hectori*, sp. nov. Carnic; Otamita, Hokonui Hills. Natural size. Trechmann Coll. (P. 186.)

6 *a*–6 *c*. *Pleurotomaria (Sisenna) hokonuiensis*, sp. nov. Carnic; Otamita, Hokonui Hills. Natural size. Trechmann Coll. (P. 186.)

Fig. 7. *Trochus (Tectus) marshalli*, sp. nov. Natural size. Carnic; Otamita, Hokonui Hills. Marshall Coll. (P. 187.)

Figs. 8 *a* & 8 *b*. *Patella (Capulus ?) nelsonensis*, sp. nov. Ladino-Carnic; Eighty-Eight Valley, Nelson. Natural size. Gutta-percha squeeze. N.Z. Geol. Surv. Coll. (P. 185.)

Plate XIX.

Fig. 1. *Pseudomonotis ochotica* var. *densistriata* Teller. Upper Noric; Garden Gully, near Wairoa Gorge, Nelson. Right valve. Seven-eighths of the natural size. Trechmann Coll. (P. 193.)

2. Ditto, var. *ambigua* Teller. Same locality. Right valve. Natural size. Gutta-percha squeeze. Trechmann Coll. (P. 193.)

3. Ditto, cf. var. *pachypleura* Teller. Same locality. Left valve. Seven-eighths of the natural size. Trechmann Coll. (P. 193.)

4. Ditto, cf. var. *sparsicostata* Teller. Same locality. Left valve. Seven-eighths of the natural size. Trechmann Coll. (P. 193.)

5. Ditto, var. *eurhachis* Teller. Same locality. Right valve. Slightly reduced. Trechmann Coll. (P. 193.)

6. Ditto, var. *acutecostata* nov. Same locality. Right valve. Seven-eighths of the natural size. Gutta-percha squeeze. Trechmann Coll. (P. 194.)

7. Ditto, var. *acutecostata* nov. Same locality. Left valve. Seven-eighths of the natural size. Trechmann Coll. (P. 194.)

8. Ditto, very small, cf. var. *pachypleura* Teller. Same locality. Left valve. Seven-eighths of the natural size. Trechmann Coll. (P. 193.)

Figs. 9 *a* & 9 *b*. *Pseudomonotis richmondiana* Zittel. Noric; eastern slopes of Mount Heslington, Nelson. *a* = right valve; *b* = left valve. Seven-eighths of the natural size. N.Z. Geol. Surv. Coll. (P. 194.)

Fig. 10. *Monotis salinaria* Bronn. Noric (?); Okuku, Canterbury. Seven-eighths of the natural size. Left valve. N.Z. Geol. Surv. Coll. (P. 195.)

Plate XX.

Fig. 1. *Monotis salinaria* Bronn, var. *intermedia* nov. Noric (?); Okuku, Canterbury. Left valve. Natural size. N.Z. Geol. Surv. Coll. (P. 196.)

2. *Monotis salinaria* Bronn, var. *hemispherica* nov. Noric (?); Okuku, Canterbury. Left valve. Natural size. N.Z. Geol. Surv. Coll. (P. 196.)

3. Ditto, same locality. Right valve. Natural size. N.Z. Geol. Surv. Coll. (P. 196.)

Fig. 4. *Hokonuia limæformis*, gen. et sp. nov. Carnic; Otamita, Hokonui Hills. Right valve. Natural size. Trechmann Coll. (P. 204.)

Figs. 5 *a* & 5 *b*. *Hokonuia* cf. *rotundata*, sp. nov. Carnic; *Mytilus-problematicus* Bed, Nugget Point, Otago. *a* = left valve; *b* = anterior portion of beak-region of the same specimen. Natural size. Trechmann Coll. (P. 205.)

Fig. 6. *Halobia zitteli* Lindström, var. *zealandica* nov. Carnic; Mount Heslington, Nelson. Right valve. Two-thirds of the natural size. Trechmann Coll. (P. 197.)

7. *Daonella indica* Bittner. Ladino-Carnic; Caroline Cutting, Hokonui Hills. Portion of a large right valve. Natural size. Trechmann Coll. (P. 196.)

8. *Mytilus (?) problematicus* Zittel. Carnic; Eighty-Eight Valley, near Nelson. Left valve of a small specimen. Natural size. Trechmann Coll. (P. 201.)

Figs. 9 *a* & 9 *b*. *Mytilus (?) mirabilis*, sp. nov. Carnic; *Mytilus-problematicus* Bed, Eighty-Eight Valley, near Nelson. Right valve: *a*=anterior; *b*=posterior view. Half of the natural size. Trechmann Coll. (P. 202.)

Plate XXI.

Fig. 1. *Halobia zitteli* Lindström, var. *zealandica* nov. Carnic; Otamita, Hokonui Hills. Seven-eighths of the natural size. Right valve. Trechmann Coll. (P. 197.)

2. Ditto. Same locality. Seven-eighths of the natural size. Left valve. Trechmann Coll. (P. 197.)

3. *Halobia hochstetteri* Mojsisovics. Carnic; Mount Heslington, Nelson. Natural size. Right valve. Trechmann Coll. (P. 199.)

4. *Halobia* cf. *austriaca* Mojsisovics. Carnic; Otamita, Hokonui Hills. Seven-eighths of the natural size. Right valve. Trechmann Coll. (P. 200.)

5. *Daonella indica* Bittner. Ladino-Carnic; Caroline Cutting, Hokonui Hills. Seven-eighths of the natural size. Trechmann Coll. (P. 196.)

6. *Pleurophorus zealandicus*, sp. nov. Carnic; Otamita, Hokonui Hills. Somewhat reduced. Left valve. Marshall Coll. (P. 212.)

7. *Cardiomorpha (?) nuggetensis*, sp. nov. Carnic; Nugget Point, Otago. Somewhat reduced. Trechmann Coll. (P. 189.)

8. *Anodontophora edmondiiformis*, sp. nov. Carnic; Otamita, Hokonui Hills. Somewhat reduced. Left valve. Trechmann Coll. (P. 208.)

9. *Anodontophora ovalis*, sp. nov. Carnic; Otamita, Hokonui Hills. Somewhat reduced. Trechmann Coll. (P. 208.)

10. *Anodontophora angulata*, sp. nov. Carnic; Otamita, Hokonui Hills. Somewhat reduced. Trechmann Coll. (P. 208.)

11. *Palæocardita quadrata*, sp. nov. Carnic; Nugget Point, Otago. Natural size. Left valve. Trechmann Coll. (P. 212.)

12. *Macrodon* cf. *curionii* Bittner. Carnic; Otamita, Hokonui Hills. Natural size. Left valve. Trechmann Coll. (P. 191.)

13. *Macrodon* sp. Carnic; Mount Heslington, Nelson. Natural size. Gutta-percha squeeze. Interior of right valve. N.Z. Geol. Surv. Coll. (P. 191.)

14. *Pseudoplacunopsis placentoides*, sp. nov. Carnic; Otamita, Hokonui Hills. Natural size. Attached valve. Trechmann Coll. (P. 209.)

15. Ditto. Carnic; Otamita, Hokonui Hills. Natural size. Upper valve. Trechmann Coll. (P. 209.)

16. *Lima (Limatula)* cf. *pichleri* Bittner. Carnic; Mount Heslington, Nelson. Natural size. Gutta-percha squeeze. Left valve. Trechmann Coll. (P. 206.)

17. *Megalodon globularis*, sp. nov. Carnic; north side of entrance of Wairoa Gorge, Nelson. Natural size. Gutta-percha squeeze. Trechmann Coll. (P. 209.)

Fig. 18. *Pecten* sp. Carnic; Nugget Point, Otago. Natural size. Gutta-percha squeeze. Left valve (?). Trechmann Coll. (P. 206.)
19. *Cassianella* sp. Carnic; Otamita, Hokonui Hills. Natural size. Left valve. Trechmann Coll. (P. 206.)
20. *Leda semicrenulata*, sp. nov. Carnic; Otamita, Hokonui Hills. Natural size. Trechmann Coll. (P. 191.)
21. *Palæoneilo otamitensis*, sp. nov. Carnic; Otamita, Hokonui Hills. Natural size. Right valve. Trechmann Coll. (P. 190.)
22. *Palæoneilo* cf. *præacuta* Klipstein. Carnic; Otamita, Hokonui Hills. Natural size. Trechmann Coll. (P. 190.)

Plate XXII.

Fig. 1. *Hokonuia rotundata*, gen. et sp. nov. Carnic. Mount Heslington, Nelson. Natural size. Gutta-percha squeeze. Right valve. N.Z. Geol. Surv. Coll. (P. 205.)
2 *a*. *Hokonuia limæformis*, sp. nov. Carnic; Otamita, Hokonui Hills. Two-thirds of the natural size. Right valve. Trechmann Coll. (P. 204.)
2 *b*. Same specimen. Anterior portion of hinge showing tongue-like shelly process. Natural size. (P. 204.)
3. *Hokonuia* cf. *rotundata*, sp. nov. Carnic; Eighty-Eight Valley, Nelson. Natural size. Gutta-percha squeeze. Interior of left valve. Trechmann Coll. (P. 205.)
Figs. 4 *a* & 4 *b*. *Hokonuia* cf. *rotundata*, sp. nov. Carnic; Wairoa Gorge, Nelson. Three-quarters of the natural size. Left valve; *b*= anterior view. N.Z. Geol. Surv. Coll. (P. 205.)
Fig. 5. *Hokonuia limæformis*, sp. nov. Carnic; Otamita, Hokonui Hills. Right valve. Natural size. Trechmann Coll. (P. 204.)
6. *Anisocardia parvula*, sp. nov. Carnic; Otamita, Hokonui Hills. Thrice the natural size. Gutta-percha squeeze. Right valve. Trechmann Coll. (P. 213.)
7. Ditto. Same locality. Thrice the natural size. Gutta-percha squeeze. Left valve. Trechmann Coll. (P. 213.)
8. *Myophoria otamitensis*, sp. nov. Carnic; Otamita, Hokonui Hills. Natural size. Trechmann Coll. (P. 211.)
9. *Myophoria heslingtonensis*, sp. nov. Carnic; Mount Heslington, Nelson. Thrice the natural size. Gutta-percha squeeze. Right valve. N.Z. Geol. Surv. Coll. (P. 211.)
10. *Myophoria nuggetensis*, sp. nov. Carnic; Nugget Point, Otago. Natural size. Gutta-percha squeeze. Trechmann Coll. (P. 210.)
11. *Pinna* sp. Carnic; Eighty-Eight Valley, Nelson. Natural size. Left valve. N.Z. Geol. Surv. Coll. (P. 206.)

Plate XXIII.

Figs. 1 *a* & 1 *b*. *Halorella zealandica*, sp. nov. Ladino-Carnic; Caroline Cutting, Hokonui Hills. Natural size. Cast of ventral and dorsal valves. Trechmann Coll. (P. 216.)
Fig. 2. Ditto. Same locality. Natural size. Gutta-percha squeeze of ventral valve. Trechmann Coll.
3. Ditto. Same locality. Natural size. Gutta-percha squeeze of ventral beak and dorsal valve. Trechmann Coll.
4. *Halorella* sp. cf. *pedata* var. *multicostata* Bittner. Carnic; Eighty-Eight Valley, Nelson. Natural size. Dorsal valve. N.Z. Geol. Surv. Coll. (P. 217.)
5. *Dielasma zealandica*, sp. nov. Ladino-Carnic; Caroline Cutting, Hokonui Hills. Three-quarters of the natural size. Cast, dorsal aspect. Trechmann Coll. (P. 217.)
6. '*Terebratula*' *pachydentata*, sp. nov. Carnic; Otamita, Hokonui Hills. Natural size. Dorsal aspect. Trechmann Coll. (P. 218.)

Fig. 7. *Terebratula (Cœnothyris ?)* sp. Noric, *Pseudomonotis* Bed; Richmond, Nelson. Natural size. Gutta-percha squeeze. Dorsal aspect. Trechmann Coll. (P. 218.)

8. *Terebratula* cf. *hungarica* Bittner. Carnic; Otamita, Hokonui Hills. Natural size. Dorsal aspect. Trechmann Coll. (P. 219.)

9. *Mentzelia* cf. *ampla* Bittner. Rhætic; Kawhia. Natural size. Dorsal aspect. Trechmann Coll. (P. 228.)

Figs. 10 *a* & 10 *b*. *Mentzelia kawhiana*, sp. nov. Rhætic; Kawhia. Natural size. *a*=ventral; *b*=dorsal aspect. Trechmann Coll. (P. 228.)

Fig. 11. *Mentzeliopsis spinosa*, gen. et sp. nov. Kaihiku Beds, Ladino-Carnic; Caroline Cutting, Hokonui Hills. Natural size. Gutta-percha squeeze of dorsal valve. Trechmann Coll. (P. 230.)

12. Ditto. Same locality. Natural size. Gutta-percha squeeze of another dorsal valve. Trechmann Coll.

13. Ditto. Same locality. Natural size. Gutta-percha squeeze of a ventral valve. Trechmann Coll.

14. Ditto. Same locality. Natural size. Gutta-percha squeeze of another ventral valve. Trechmann Coll.

15. Ditto. Same locality. Natural size. Gutta-percha squeeze of the interior of a ventral valve showing the median septum and the external spines. Trechmann Coll.

16. Ditto. Kaihiku Beds; North Peak, Hokonui Hills. Cast, the spines destroyed, showing the ventral median septum and dental plates. Natural size. N.Z. Geol. Surv. Coll.

17. *Mentzeliopsis horrida*, sp. nov. Kaihiku Beds, Ladino-Carnic; Caroline Cutting, Hokonui Hills. Gutta-percha squeeze of dorsal valve. Natural size. Trechmann Coll. (P. 230.)

18. Ditto. Same locality. Gutta-percha squeeze of the ventral valve of another specimen. Natural size. Trechmann Coll.

Figs. 19 *a* & 19 *b*. *Spiriferina (?) carolinæ*, sp. nov. Kaihiku Beds, Ladino-Carnic; Caroline Cutting, Hokonui Hills. Natural size. Gutta-percha squeeze: *a*=the interior; *b*=the exterior of a ventral valve. Trechmann Coll. (P. 226.)

Fig. 20. Ditto. Same locality. Natural size. Gutta-percha squeeze of the exterior of a dorsal valve. Trechmann Coll.

21. *Retzia schwageri* Bittner. Carnic; Mount Heslington, Nelson. Gutta-percha squeeze. Dorsal aspect. Natural size. Trechmann Coll. (P. 227.)

Plate XXIV.

Fig. 1. *Spiriferina diomedea*, sp. nov. Rhætic. South Hillend, near the Hokonui Hills. Gutta-percha squeeze of a dorsal valve and part of the ventral area. Natural size. Marshall Coll. (P. 222.)

2. Ditto. Rhætic: Nugget Point, Otago. Natural size. Dorsal aspect, the wings broken. N.Z. Geol. Surv. Coll. (P. 222.)

3. *Spiriferina acutissima*, sp. nov. Noric (?); east side of Mount Heslington, Nelson. Gutta-percha squeeze, dorsal aspect. Natural size. N.Z. Geol. Surv. Coll. (P. 221.)

4. *Spiriferina gypaetus*, sp. nov. Noric (?); South Peak, Benmore, Hokonui Hills. Gutta-percha squeeze, dorsal aspect. Natural size. N.Z. Geol. Surv. Coll. (P. 221.)

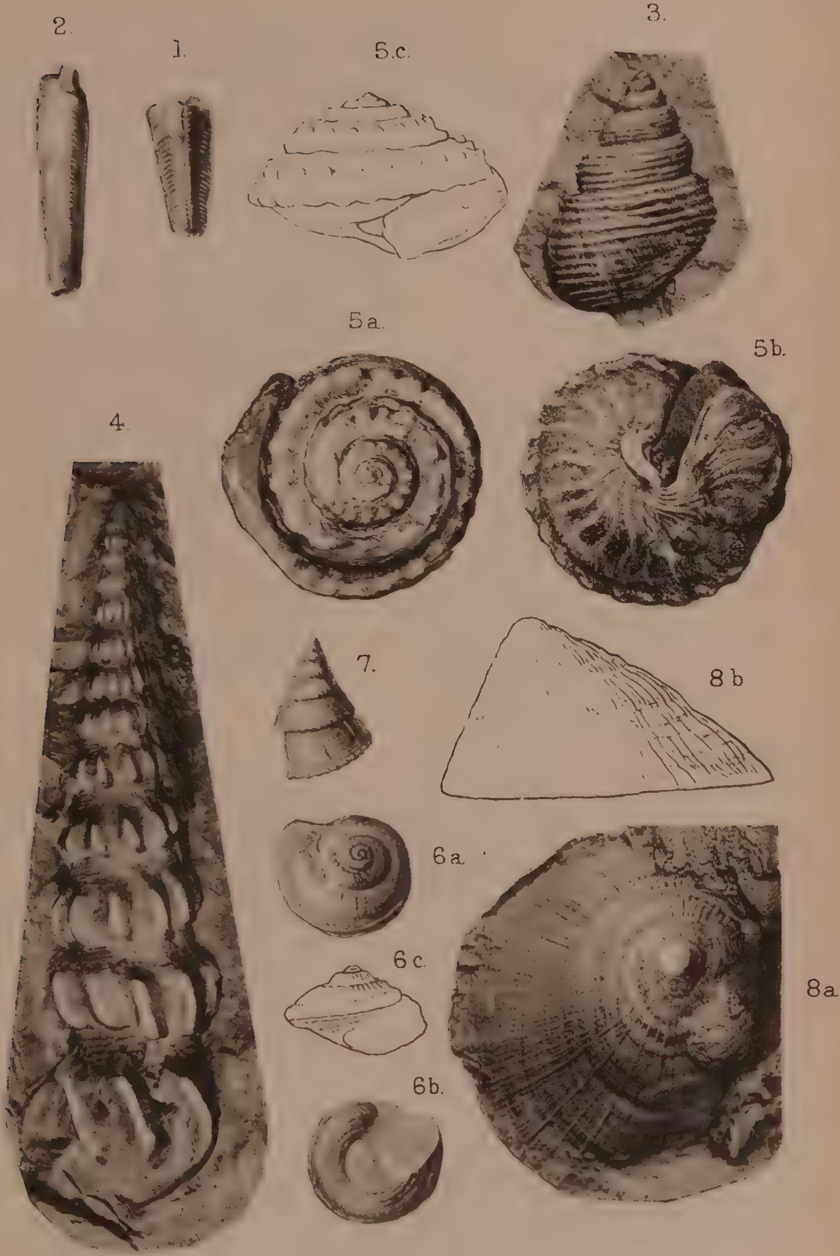
5. *Spiriferina* cf. *austriaca* Suess. Lower Carnic (?); Mount Potts. Dorsal aspect. Natural size. N.Z. Geol. Surv. Coll. (P. 224.)

Figs. 6-8. *Spiriferina nelsonensis*, sp. nov. Carnic; western slopes of Mount Heslington, Nelson. Natural size. Gutta-percha squeezes: 6=a dorsal valve and ventral area; 7=exterior of a ventral valve; 8=ventral area; of three different examples. Trechmann Coll. (P. 223.)

C.T.T., photo.

Bemrose, Collo., Derby.

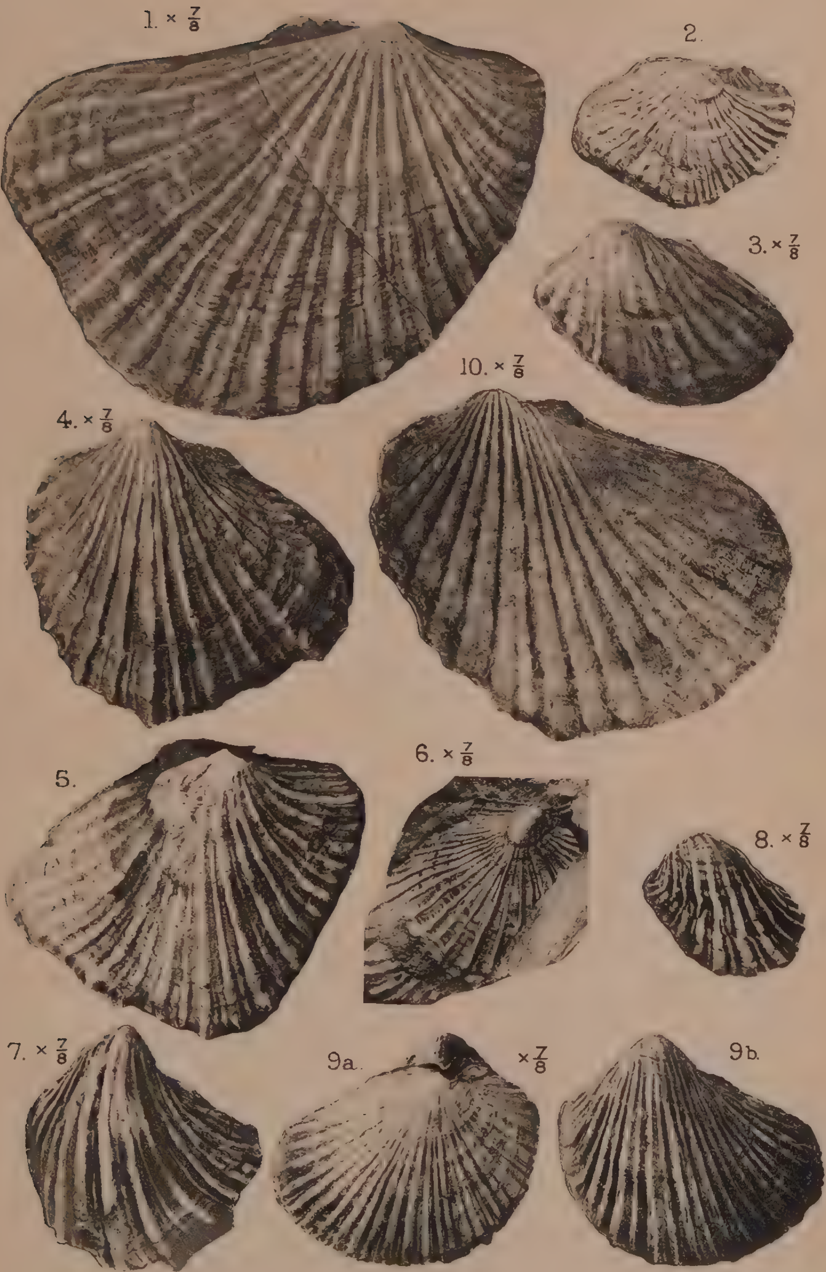
TRIASSIC CEPHALOPODA FROM NEW ZEALAND.



G. M. Woodward, del.
C.T.T., photo.

Bemrose, Collo., Derby.

TRIASSIC GASTEROPODA, etc., from NEW ZEALAND.



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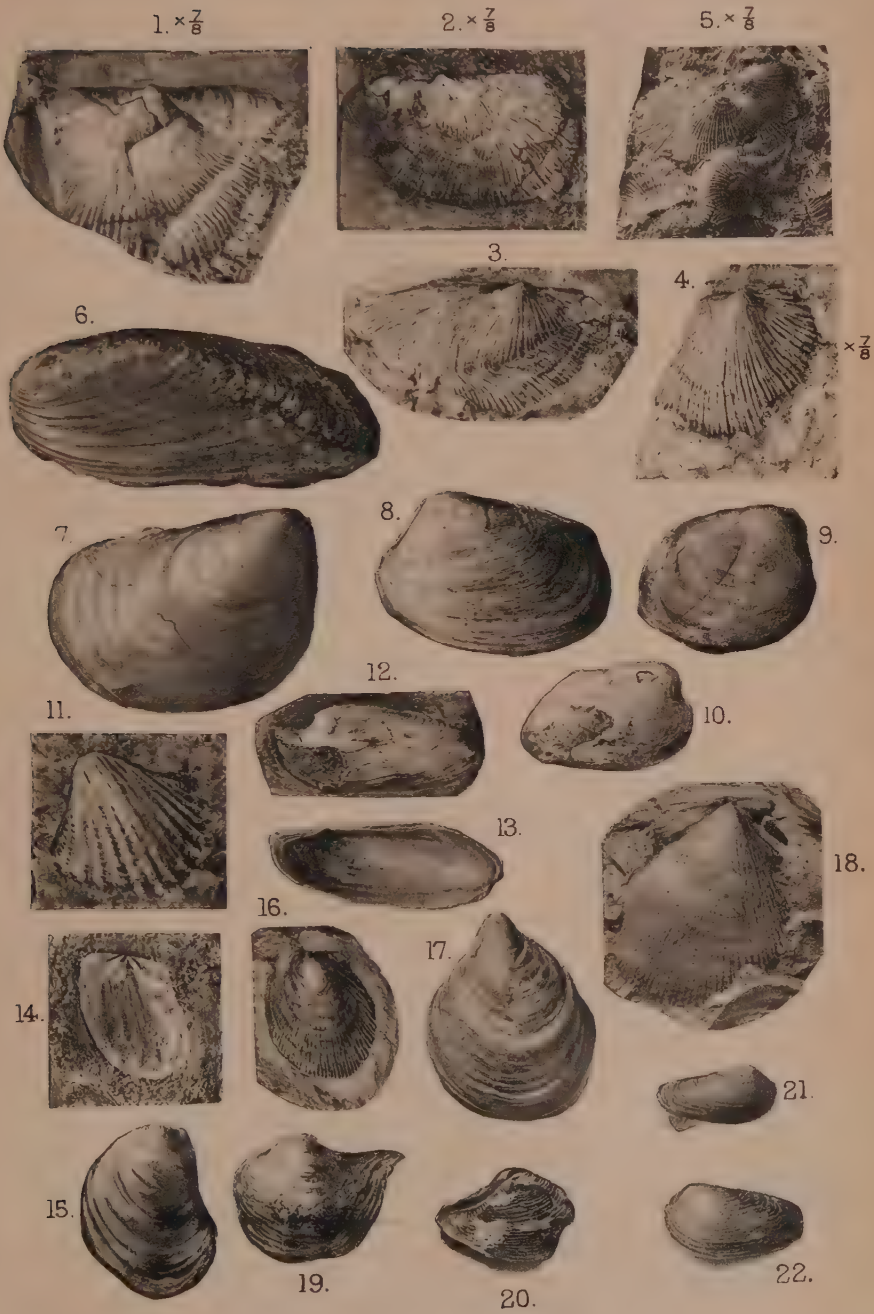
PSEUDOMONOTIS AND MONOTIS.

G. M. Woodward, del.

Bemrose. Collo. Derby.

TRIASSIC LAMELLIBRANCHS FROM NEW ZEALAND.



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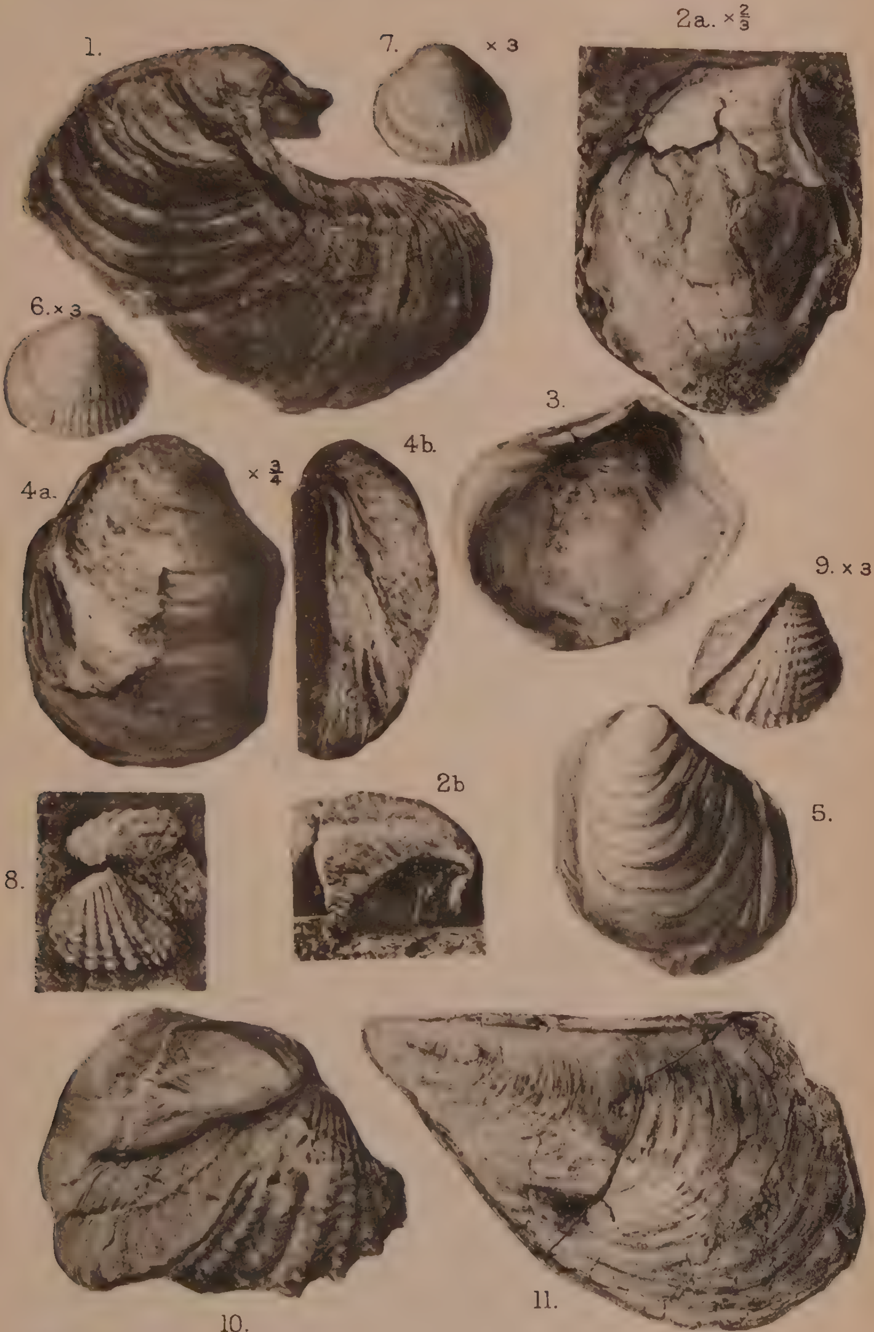
TRIASSIC LAMELLIBRANCHS FROM NEW ZEALAND.



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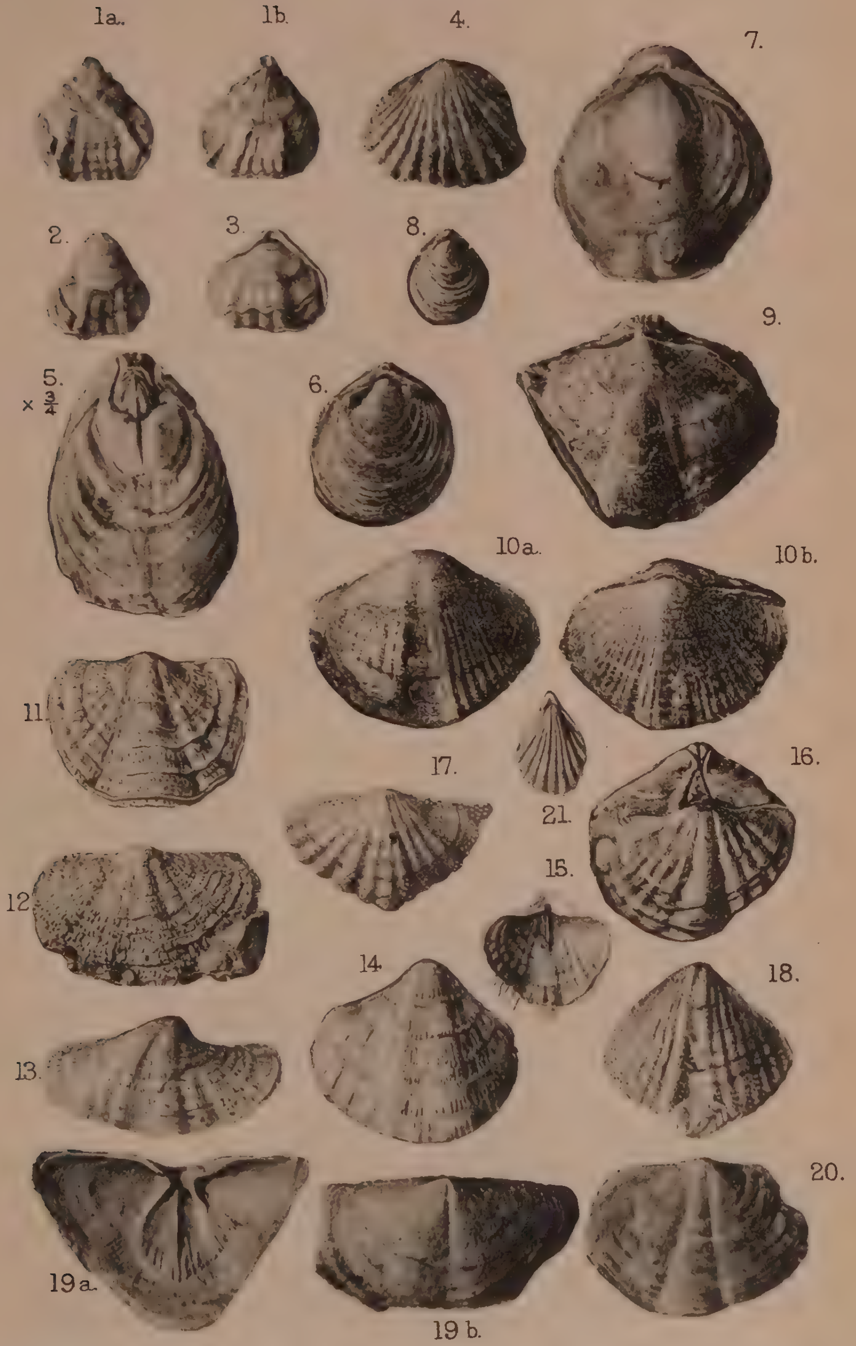
TRIASSIC LAMELLIBRANCHS FROM NEW ZEALAND.



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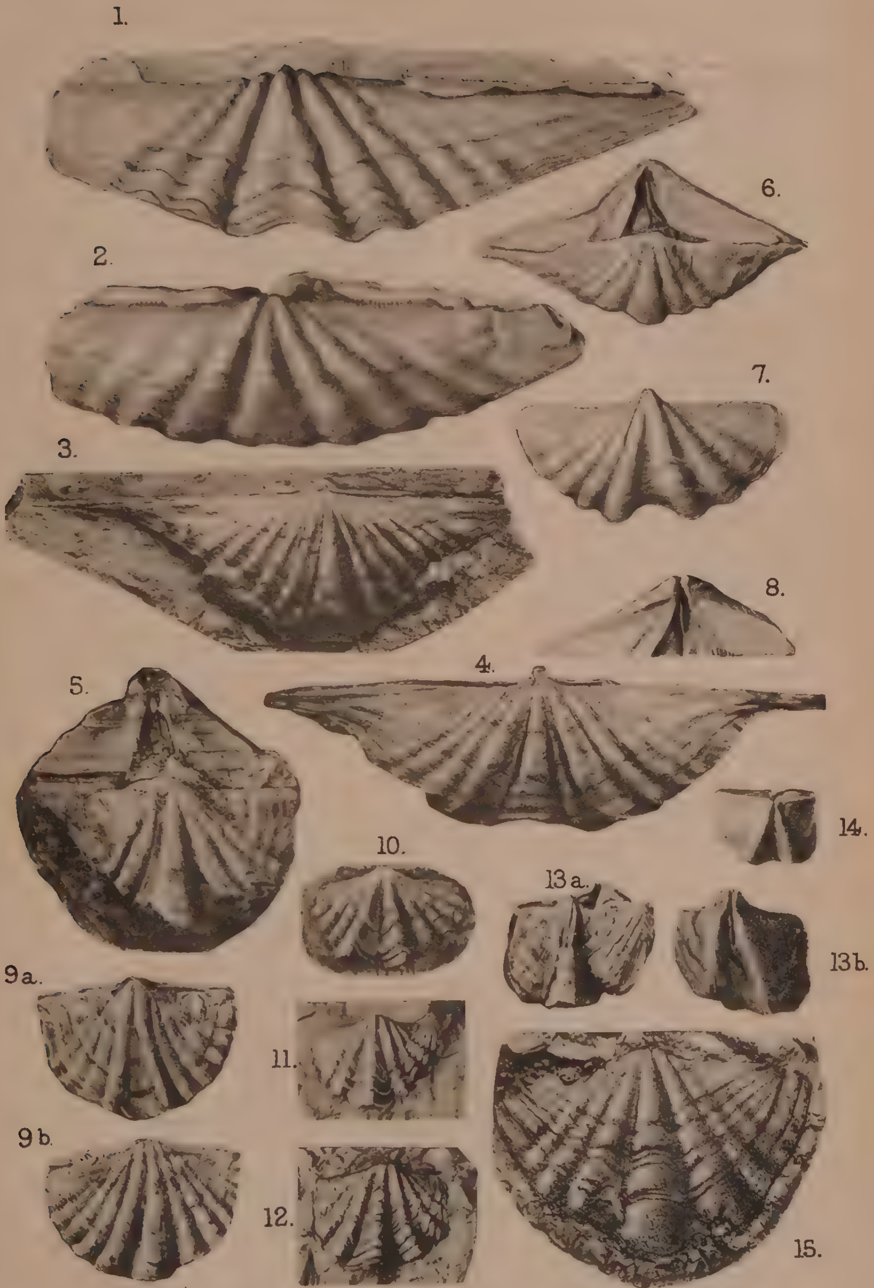
TRIASSIC BRACHIOPODA FROM NEW ZEALAND.



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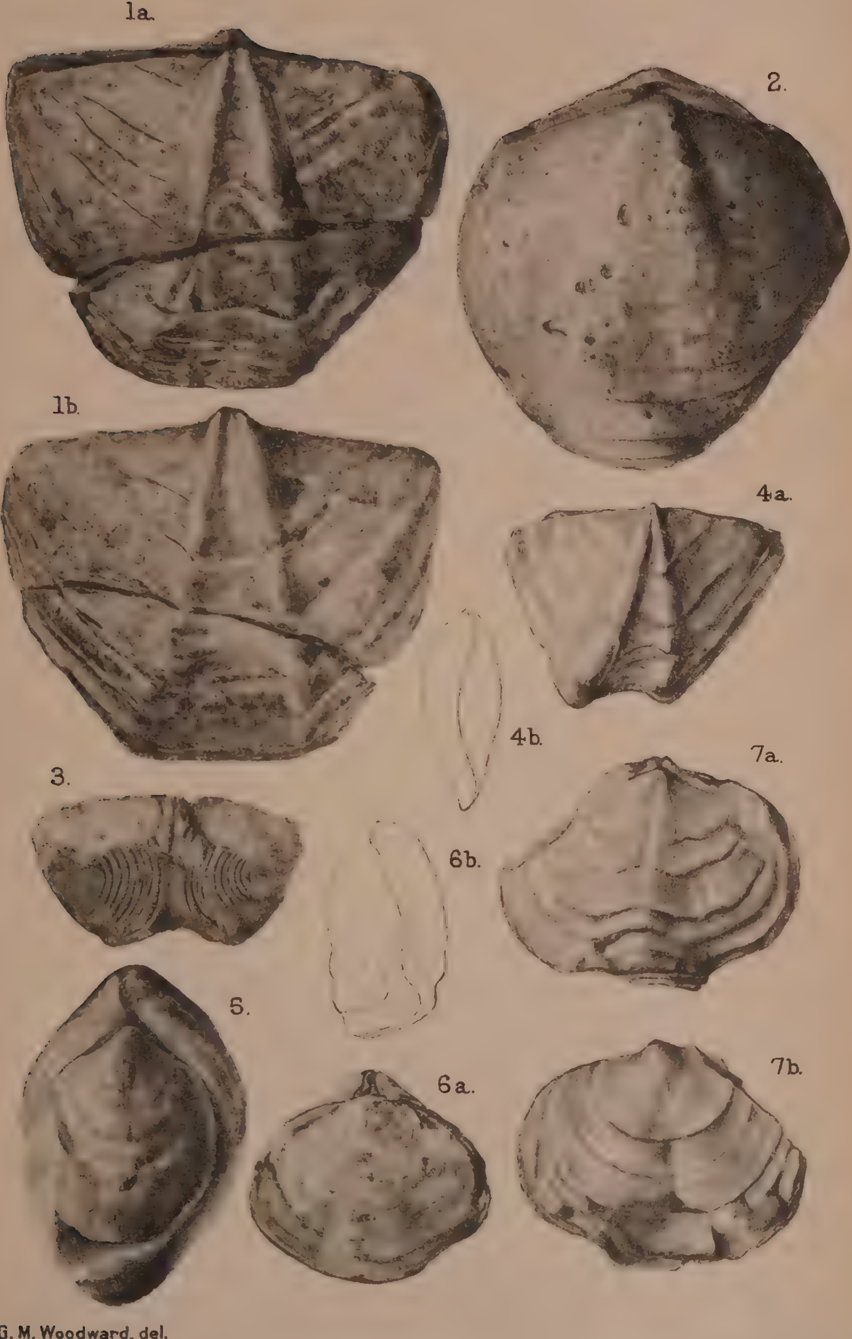
TRIASSIC SPIRIFERINÆ FROM NEW ZEALAND.



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TRIASSIC BRACHIOPODA FROM NEW ZEALAND.

Figs. 9 *a* & 9 *b*. *Spiriferina otamitensis*, sp. nov. Carnic; Otamita, Hokonui Hills. *a*=dorsal; *b*=ventral valve of a rather crushed example. Natural size. Trechmann Coll. (P. 225.)

10–12. *Spiriferina fragilis* Schlotheim. Kaihiku Beds, Ladino-Carnic; Caroline Cutting, Hokonui Hills. Natural size. Gutta-percha squeezes: 10=ventral; 11 & 12=dorsal valves. Natural size. Trechmann Coll. (P. 219.)

13 *a* & 13 *b*. *Spiriferina suessi* Winkler, var. *australis* nov. Carnic, *Halobia* Beds; Mount Heslington, Nelson. Natural size. *a*=dorsal; *b*=ventral aspects of the same example, a cast. Trechmann Coll. (P. 225.)

Fig. 14. Ditto. Same locality. Gutta-percha squeeze of the exterior of a ventral valve. Natural size. Trechmann Coll.

15. *Spiriferina kaihikuana*, sp. nov. Kaihiku Beds, Ladino-Carnic; Eighty-Eight Valley, Nelson. Gutta-percha squeeze of the exterior of a dorsal valve. Natural size. N.Z. Geol. Surv. Coll. (P. 220.)

Plate XXV.

Figs. 1 *a* & 1 *b*. *Hectoria bisulcata*, gen. et sp. nov. (Hector). Rhætic; Kawhia. Natural size. *a*=dorsal; *b*=ventral aspect. Trechmann Coll. (P. 225.)

Fig. 2. *Hectoria tumida*, sp. nov. Rhætic; Benmore, Hokonui Hills. Natural size. Gutta-percha squeeze of a ventral beak and a dorsal valve. Trechmann Coll. (P. 236.)

3. *Hectoria* sp. Taylor's Creek, Hokonui Hills. Natural size. Weathered cast showing the spiralia. Ventral aspect. N.Z. Geol. Surv. Coll. (P. 233.)

Figs. 4 *a* & 4 *b*. *Hectoria cuneiformis*, sp. nov. Jurassic, Taylor's Creek, Hokonui Hills. Natural size. *a*=ventral aspect; *b*=section. N.Z. Geol. Surv. Coll. (P. 237.)

Fig. 5. *Spirigera kaihikuana*, sp. nov. Ladino-Carnic; Cowan's Railway-station, Hokonui Hills. Natural size. Dorsal aspect. N.Z. Geol. Surv. Coll. (P. 231.)

Figs. 6 *a* & 6 *b*. *Spirigera wreyi* Zittel. Carnic; western slope of Mount Heslington, Nelson. Natural size. *a*=dorsal aspect; *b*=section. Trechmann Coll. (P. 231.)

Figs. 7 *a* & 7 *b*. *Spirigera manzavinioides*, sp. nov. Carnic; Otamita, Hokonui Hills. Natural size. *a*=dorsal; *b*=ventral aspect. Trechmann Coll. (P. 232.)

Discussion.

Dr. F. A. Bather was glad to find a British geologist and palæontologist tackling these complicated problems of New Zealand geology with such success. Ever since he himself had described *Torlessia*, he had wished to know the age of the supposed Maitai Beds near Mount Torlesse, where this presumed annelid was found. Did the Author include them in those which he now referred to the Permo-Carboniferous, or would he parallel them with the Yakutat Slates of Liassic age, or would he leave them in the Trias?

The Author, in reply, stated that the true relationship of the Mount-Torlesse Annelid Beds was still one of the unsolved problems of New Zealand geology. The question of their stratigraphy is discussed by McKay and others, and the evidence seems to show

that they form the upper part of the Maitai Series. The Annelid Beds have not been traced in the Nelson district, the classical area of the Maitai Series; but he had himself found a piece of annelid-like tube in the Maitai Limestone of the Wairoa Gorge, accompanied by *Zaphrentis* and Permo-Carboniferous brachiopods.

He did not think the Mount-Torlesse Annelid Beds in any way equivalent to the Yakutat Slates of Alaska, as he had shown that the large bivalve in the Maitai Argillites overlying the Limestone near Nelson, formerly supposed to be *Inoceramus*, is apparently identical with *Aphanaia* L. G. de Koninck, of the Permo-Carboniferous of New South Wales.

Inoceramya Ulrich, of the Yakutat Slates, is a shell of the *Inoceramus* group, and bears a row of areal ligament-pits. The Lias, or at least the Lower Jurassic, is a well-defined formation in New Zealand, where it overlies the Trias, and in no way resembles the Annelid Beds.

He felt much interest in the fact that Dr. Bather had determined the scanty crinoid remains that he collected in the Kaihiku Beds as rather of Upper than of Middle Triassic age. All evidence that these deposits were Permian or Lower Trias seemed now entirely removed.

8. *The* Triassic Crinoids *from* New Zealand, *collected by* Dr. C. T. Trechmann. By Francis Arthur Bather, M.A., D.Sc., F.R.S., F.G.S. (Read February 7th, 1917.)

Dr Trechmann has kindly presented to the British Museum (Natural History) a stem-fragment and a piece of calcareous sandstone containing imprints of various columnals, and has asked me to furnish some notes on them. Since these are the first Triassic crinoids to be described from New Zealand, their adequate description seems warranted, despite their fragmentary condition. All are believed to represent new species.

In 1909 most of the Triassic crinoids known up to date were discussed by me in 'Triassic Echinoderms of Bakony,' [1] and the terminology here employed is explained in that memoir. Since then the only professedly new forms made known are those contained in Clark & Twitchell, 1915, 'The Mesozoic & Cenozoic Echinodermata of the United States' (U.S. Geol. Surv. Monogr. liv). These, therefore, are discussed here at greater length than the better-known European species, and for one of them a new specific name is proposed.

[Mr. G. C. Martin, in a paper on 'Triassic Rocks of Alaska,' published December 1916 (Bull. Geol. Soc. Amer. vol. xxvii, pp. 685–718), but not received here until June 1917, records specimens of '*Pentacrinus*.' These, which belong to two new species of *Isocrinus*, are also described and compared.]

Entrochus undatus, sp. nov. (Figs. 1 & 2, p. 248.)

Diagnosis.—Trochitæ with smooth, faintly convex side-faces; ratio of height to diameter circa 0·18; joint-face with about 25 coarse ill-developed ridges, radiating from the centre about halfway to the periphery, where they merge into a few broad, irregular waves.

Locality.—Eighty-Eight Valley, Nelson, (N.Z.).

Horizon.—Kaihiku Beds, Ladino-Carnic.

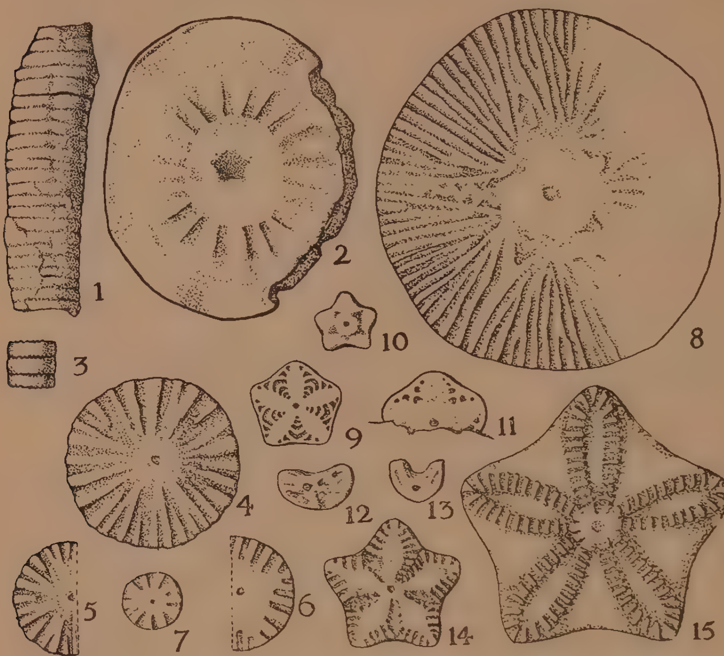
Material.—A stem-fragment consisting of 24 columnals or portions of columnals, broken cleanly across at the joint-face, between the 5th and 6th, and worn all down one side, especially towards the other end of the fragment. British Museum, Geological Department, E 22185.

Description.—Cylindrical.

Length of fragment = 38 mm.
Average height of columnal, as calculated = 1·58 mm.
Greatest height of a columnal, as measured = 1·8 mm.
Least height of a columnal, as measured = 1·5 mm.
Diameter = 8·2 mm. at the more imperfect end; = 10 mm. at the other.
Ratio of height to diameter = 0·18.
Diameter of lumen = about 0·8 mm.

[1] 'Result. Wissensch. Erforsch. des Balatonsees' vol. i, Pal. Anhang.

Entrochi and Pentacrini from New Zealand and North America.



[Figs. 1 and 3 are of the natural size. All the rest are enlarged 4 diameters. Drawn by Miss Margaret Tempest.]

Entrochus undatus. (Pp. 247–49.)

Fig. 1. Holotype. Side view; the thicker suture-line, fifth from the top, represents the division between the two fragments. [E 22185.]
2. Holotype. Joint-face at the top of the larger fragment.

Entrochus ternio. (P. 249-52.)

Fig. 3. Holotype. Side view. [E 22186.]
4. Holotype. Joint-face.
5. Group B. Joint-face with the characters of the holotype.
6. Group B. Joint-face with ridges pentamerously fasciculated.
7. Group C. Joint-face of young.

Encrinus hyatti W. B. Clark. (P. 251.)

Fig. 8. Joint-face. [E 6481.]

Isocrinus trechmanni. (Pp. 252–53.)

Fig. 9. Normal joint-face. In this example there is a marked peripheral rim, and the radial ridge-groups are gable-shaped. [E 22186.]
10. Joint-face of a small epizygal with no ridges. [E 22187.]
11. Syzygial joint-face with traces of ridges. [E 22187.]
12. A wide asymmetrical brachial. [E 22187.]
13. A pinnular, or a symmetrical brachial from the distal region. [E 22187.]

Isocrinus cupreus. (Pp. 255–56.)

Fig. 14. Normal joint-face. In this the secondary or accidental radial depressions are less marked than in most. [E 22178.]

Isocrinus gravinæ. (P. 256.)

Fig. 15. Normal joint-face. [E 22181.]

Sides smooth, faintly convex, rising about 0·1 mm. above the suture-line.

Suture-lines broadly and irregularly waved, not crenelate in the ordinary sense.

The joint-face shows faint traces of radiating ridges in the central area, but at about halfway to the periphery these die away with varying rapidity. The number of these ridges is estimated at 25; it is not possible to see whether they are grouped by fives to any extent. The ridges and grooves are of equal size. The peripheral half of the joint-face is almost smooth; but in places there can be detected the traces of the radiate ridges, also faint concentric grooves. The whole surface is thrown into very slight broad waves, 5 or 6 in all, which bear no obvious relation to the ridges.

The lumen is obscurely pentagonal, and is indicated in the fossil by a calcite infilling of darker colour. Within this, at all four places where it is exposed there is visible a structure with a light border, which may be interpreted as probably an axial vessel, possibly with five chambers (compare Bather, 1909, pp. 41, 42).

Relations of the species.—The circular section, smooth exterior, apparent absence of cirri, small lumen, and radiating ridges on the joint-face: all these are characters of the *Encrinus* stem, and to that genus the present specimen probably belongs. None the less, in the absence of evidence from the crown, and in view of the distinctive characters of the joint-face, it is safer to give the specimen for the present the non-committal name *Entrochus*.

From all known species of *Encrinus*, and from all Entrochi as yet described from Triassic rocks, the *Entrochus* here described differs in the substitution of broad irregular waves for the radiating ridges in the peripheral area of the joint-face, resulting in a waved non-crenelate suture-line. Hence the trivial name, *undatus*, waved.

ENTROCHUS TERNIO, sp. nov. (Figs. 3–7, p. 248.)

Diagnosis.—Trochitæ with smooth, faintly convex side-faces; ratio of height to diameter=0·35 (more in young); suture depressed, crenelate; joint-face with a raised central area, and from 20 to 30 well-marked ridges, of which two-thirds tend to constitute forked pairs starting from the centre, and one-third to be shorter ridges intercalated between the pairs.

Locality.—Caroline Cutting, Hokonui Hills, Southland (N.Z.).

Horizon.—Kaihiku Beds, Ladino-Carnic.

Material.—Various imprints of columnals on a fragment of calcareous sandy matrix with iron-stained imprints and internal casts of *Spiriferina fragilis*, *Dielasma* cf. *himalayana*, *Mentzeliopsis*, and *Isocrinus*. British Museum, Geological Department, E 22186. The imprints of columnals may be grouped under three headings. (A) A stem-fragment consisting of 3 columnals,

and showing the clear impression of one joint-face. This, which is believed to represent the adult stage, is fixed on as the holotype. (B) Three smaller separated columnals, visible in rather imperfect imprints, not far from the holotype. (C) Two small united columnals, and, at 16 mm. distance from them, the imprint of a small joint-face. These three sets will now be described in order.

Description of A, the holotype (figs. 3 & 4, p. 248).—Cylindrical.

Length of fragment = 5·8 mm.
Diameter = 5·7 mm.
Height of a columnal, as measured = 2 mm. Ratio to diameter = 0·35.
Diameter of lumen = circa 0·4 mm. (not more).

Sides smooth, faintly convex; suture depressed.

Suture-lines with large, rounded, well-marked crenellæ.

The joint-face shows a raised area round the lumen, and outside this about 28 radiating ridges, which tend to be arranged so that about a third start from the central area and fork, while the remaining 9 are intercalated between these pairs. It is this arrangement by threes that has suggested the trivial name *ternio*, a number containing threes.

Description of Group B (figs. 5 & 6, p. 248).—The three columnals are all of about equal size, with the following approximate measurements:—

Diameter = 3·7 mm.
Height = 1·8 mm. Ratio to diameter = 0·48.
Diameter of lumen = 0·25 mm.

In the best-preserved joint-face (fig. 5) there are about 22 ridges, arranged in pairs with a shorter one intercalated, as in the holotype.

The joint-face of the adjacent imprint (fig. 6) has a smooth and flat central area, at a level slightly below the ridges. This area is larger than in the other cases, so that the ridges are shorter. Their number is estimated at not less than 22, and they appear to lie in five fascicles of 4 or 5, those in each fascicle being parallel to the median line of that fascicle.

These smaller columnals are ranked with the holotype, as probably belonging to the same species. The characters in which they differ from the holotype are, on the whole, those of youth. With this the relatively greater height of the columnals is consistent, though perhaps rather more than might have been expected on that interpretation. I have previously suggested (1909, p. 9) that the pentamerous fasciculation of the ridges is a frequent, possibly universal, characteristic of youth in the genus *Encrinus*. It may, however, be manifested in certain regions of the stem and absent from others. In some species the character passes into the adult stage, and in genera of later origin becomes a normal feature (1909, p. 249). See p. 251, under 'Relations.'

Description of Group C (fig. 7, p. 248).—The stem-fragment composed of two columnals is cylindrical.

Diameter of columnal = 2·3 mm.
Height of columnal = 1·25 mm. Ratio to diameter = 0·54.
Diameter of lumen = 0·25 mm.

Sides smooth, very faintly convex, almost straight.

Suture-lines with large, rounded, well-marked crenellæ.

The joint-face shows a raised area round the lumen, with a diameter of about 0·6 mm., and outside this are 10 radiating ridges. rapidly broadening.

The other imprint also has 10 ridges. Its diameter is 1·6 mm.

These specimens may represent a still younger stage. If from the holotype's total of 28 we were to eliminate the shorter intercalated ridges, there would be left about 10 pairs of bifurcating ridges, and each of those pairs would in its early stage appear as a single rapidly broadening ridge.

Relations of the species.—At first sight the characters of these imprints seem of so indifferent or uncritical a nature as not to warrant the establishment of a new species. I have, however, worked through the descriptions of published species without finding any that agree with the diagnosis here presented. Perhaps one would not expect to find the same species in the European or even in the American province; but neither is there anything of the kind in the Triassic material from Timor that Prof. J. Wanner has kindly entrusted to me for description. Among European species similar joint-faces are found in the Carnic rocks rather than in the Ladinic, where the sharply-cut cog-wheel type, familiar in *Encrinus liliiformis*, is dominant.

A tendency to bifurcation and intercalation of ridges on the same plan as in *Entrochus ternio* is observable in *Entrochus insignis* Toula. Specimens of this from the type-locality in Bulgaria were most kindly sent to me by Dr. P. Bakalow (Brit. Mus., Geol. Dept., E 14076), who has proved their Triassic age [probably Raiblian]. This species shows a far more marked pentamerous fasciculation of the ridges than anything hinted at in *E. ternio*, together with a beginning of petals and radial ridge-groups.

An earlier stage of that development is found in *Encrinus hyatti* W. B. Clark (1915), from the Upper Trias of California. Clark lays stress on the bifurcating striations (which, by the way, are scarcely shown in his figure); but he has not observed other important characters. In a specimen (fig. 8, p. 248) which Prof. Clark was so good as to give me many years ago (now Brit. Mus., Geol. Dept., E 6481) there are shorter intercalated ridges as in *E. insignis*, not so regular as in *E. ternio*. Further, the ridges are clearly gathered in 5 fascicles surrounding a relatively large, raised, central area, which thrusts out 5 wedges between the fascicles, each wedge splitting (as it were) one of the ridges and compressing the other ridges into a fan as it forces the limbs of

the split one asunder. These split ridges may be the beginning of either the radial ridge-groups or the petals; their relations to the lumen are obscure, but they coincide with the angles of the periphery, which is irregularly and faintly pentagonal. The ridges of *Encrinus hyatti* are coarser than those of *Entrochus insignis*, finer than those of *E. ternio*. The characters observed are confirmed by squeezes (Brit. Mus., Geol. Dept., E 21819) very kindly made by Prof. Bassler from specimens studied by Prof. Clark and now in the U.S. National Museum.

Isocrinus trechmanni, sp. nov. (Figs. 9–13, p. 248.)

Diagnosis.—Transverse section normally a rounded pentagon, at the syzygy a rounded star. Height less than one-third of the diameter. Side-faces smooth, straight. Suture-line flush, faintly or not at all crenelate. Normal joint-face with lumen minute; central area raised, smooth, narrow, continuous with the radial crenellæ; petal-floors raised generally to the level of the crenellæ, smooth, narrow, long; radial ridge-groups about 3, inosculating more often than gable-shaped, the distal pair meeting at an angle of about 90°; peripheral crenellæ 6 to 8, passing from the interradius towards the periphery at an angle which gradually increases to a right angle in the more acentral ridges; all confluent on the periphery.

Locality.—Caroline Cutting, Hokonui Hills, Southland (N.Z.).

Horizon.—Kaihiku Beds, Ladino-Carnic.

Material.—Various imprints of columnals on the same rock-fragment as *Entrochus ternio*. British Museum, Geol. Dept., E 22186, E 22187. The holotype is the imprint of a normal joint-face on the latter piece, not the example drawn in fig. 9.

Description.—The transverse section of a normal internodal is a pentagon, usually rounded, with sides sometimes slightly convex. A few that show signs of excavation of the sides probably lay just above the nodes, and received the cirri in their hollowed sides. One such is almost a pentapetalon. Measurements of normal internodals are:—

Diameter = 2 mm., 2·3 mm., 2·8 mm.
Height = 0·75 mm.; ratio to diameter = 0·27.

Side-faces straight and unornamented.

Suture-lines flush, noncrenelate in normal internodals; perhaps obscurely crenelate at or near syzygies.

Joint-faces.—Normal internodal (fig. 9, p. 248): lumen minute, say 0·1 mm., its section not distinct; central area raised, smooth, narrow, continuous with the radial crenellæ; petal-floors raised generally to the level of the crenellæ, smooth, narrow, long; radial ridge-groups about 3, inosculating more often than gable-shaped, the adcentral pair tending to fuse with the central area, the acentral meeting at an angle of about 90°; peripheral crenellæ 3 or 5 in small ossicles, from 6 to 8 in full-sized ones (9 in the

pentapetalon), passing from the interradius towards the periphery at an angle which gradually increases to a right angle in the more acentral ridges: all confluent on the periphery.

Syzygial face (seen in one imprint, fig. 11, whether epi- or hypozygal uncertain): sides of rounded pentagon faintly excavate; lumen and central area larger than in the normal face, the area slightly raised; petal-floors wide, and flush or slightly depressed; perradial ridge-groups 2, the adcentral one a mere granule, the acentral one lambdoid with the stem broadening to form part of the peripheral rim; peripheral crenellæ restricted to one on each side of the lambdoid stem, but the rim is continuous, though faint, and a couple of slight swellings on it represent the interradial crenellæ.

There is one small imprint (fig. 10) that appears to be of an epizygal, but it is not very clear. It is a rounded star, with diameter = 1·8 mm.; IR = 1 mm.; $r = 0{\cdot}5$ mm.; lumen minute, but distinct, relatively large, apparently pentagonal; ridges invisible; petal-floors slightly depressed; rim indistinct. The side-faces of this columnal were vertically concave, and apparently bore a depressed, elliptical cirrus-facet.

Cirrals appear to be represented by imprints of a few small canaliculate ossicles.

Brachials.—There are a few scattered imprints of articular faces, which probably represent brachials of this species. There are wide brachials from the proximal region (fig. 12), narrower and more elevated ones from the distal region (fig. 13); one wide brachial shows a syzygial face. All have the axial canal well developed, and in this respect resemble the brachial from the Raiblian *Cardita*-Oolite of Rammelsbach, figured in 'Triassic Echinoderms of Bakony' (1909, pl. v, fig. 122) rather than the brachial from the Cassian Beds of Cserhát (*op. cit.* pl. v, fig. 127).

Relations of the species.—The joint-faces of three European Triassic species (*I. propinquus*, *I. hercuniæ*, *I. bavaricus*) are distinguished from *I. trechmanni* by the presence of a radial triangle. The absence of a rim and the consequent crenelation of the suture-line distinguish *I. tyrolensis*, *I. scipio*, and *I. sceptrum*. *I. amœnus* is further characterized by the marked ornament of its side-faces, and *I. candelabrum* by the long curved ridges of its joint-face. In *I. dubius* (Goldfuss) the crenellæ are confluent with the periphery, but that species, to judge from the original figures, has wider petal-floors than *I. trechmanni*, with a greater distinction between the radial ridge-groups and the peripheral ridges. *I. dubius* needs careful redescription on the basis of the original material; meanwhile, it is with it and similar forms that *I. trechmanni* should be associated.

Turning to the Triassic species of North America, the characters of which have lately been sketched by Prof. W. B. Clark (1915), we find three species, which may be discussed briefly.

Isocrinus smithi, from the Lower Trias, is represented by weathered columnals. The section in the specimen as figured is a

rounded star, with diameter = 2·85 mm. (the text says 0·5 to 2 mm.) and height = 0·8 mm. (the text says 0·33 to 1 mm.). Ratio of height to diameter = 0·28 (the text would make it 0·6 to 0·5). The lumen is said to be 'small,' but as drawn has a diameter of 0·35 mm. No other characters of the joint-face are either figured or described, although the drawing suggests that the side-faces were transversely ridged. This feature and the general outline distinguish *I. smithi* from *I. trechmanni*.

Isocrinus californicus, from the Upper Trias, is represented by well-preserved columnals. The section as drawn is a rounded star, with a diameter = 3·75 mm. (the text says 2 to 5 mm.); height = nearly 0·8 mm. (the text says 0·5 to 1 mm.). Ratio of height to diameter = from about 0·25 to 0·2. The lumen is said to be 'large and well-marked,' but as drawn has a diameter of 0·14 mm., which (as compared with *I. smithi*) would be even minute. The petals are 'narrow' and 'sharply terminated'; from the drawing it appears that the ridges are short and not confluent at the periphery, but the side-view shows no trace of crenellæ, which is curious. The side-faces appear from both drawing and photograph to be gently convex at the IR angles and sharply so at the reëntrant *r* angles, so that in the angle the sides are transversely ridged. The photograph shows rather clearly a cirral, with section circular, joint-face rimmed, central area raised, lumen minute. The scalariform sides of *I. californicus* are enough to distinguish it from *I. trechmanni*, whatever its other characters may really be.

The third species is a form recorded in 1877 by Hall & Whitfield [1] from limestone of Middle Triassic age in Nevada. They referred it with doubt to the Jurassic *Pentacrinus asteriscus* Meek & Hayden. That, however, appears to be a *Pentacrinus* sensu stricto, whereas the Triassic species is rightly referred by Prof. Clark to *Isocrinus*. Unfortunately, he neither describes nor names it. The specimen is said by him, as formerly by Whitfield in his 'List of Types,' to be in the U.S. National Museum; but Dr. Bassler, who has kindly searched, tells me that it cannot now be found. The original figure, however, is quite clear enough to serve as the basis of a diagnosis and a name. The following are therefore submitted:—

Isocrinus argenteus, sp. nov. Transverse section a slightly rounded star. Joint-face with radial triangle; lumen relatively large and quinquelobate with radial lobes; petals lanceolate, but not narrow; radial ridge-groups about 3, remainder of ridges about 15, but of these only 2 or 3 at the distal end of the petal reach the periphery. Diameter, may 'exceed one-fourth of an inch' (say 7 mm.).

Holotype. The specimen figured as *Pentacrinites asteriscus?* by Hall & Whitfield, 1877.

[1] U.S. Geol. Explor. 40th Parall., Final Rep. vol. iv, p. 280 & pl. vi, fig. 16.

[I am indebted to the Director of the United States Geological Survey for several sets of squeezes taken from the best specimens found in Alaska (G. C. Martin, 1916). It is inferred from these squeezes that the original specimens are in their natural relief. Plaster casts have therefore been taken from the squeezes in the Geological Department of the British Museum, and form the basis of the following descriptions :—

Isocrinus cupreus, sp. nov. (Fig. 14, p. 248.)

Transverse section a rounded star, with the sides of the interradial angles slightly convex. Normal joint-face with lumen minute (under 0·25 mm.) and central area raised in a rim round it; petals broadly lanceolate, floors flush with the ridges or but slightly lower; radial ridge-groups about 4, their crenellæ inosculating, and apparently fragile, merging into peripheral crenellæ, which are 8 or 9, non-confluent. Suture crenelate all round.

Approximate measurements :—IR = 2·5 mm.; $r = 1·5$ mm.; reëntrant angle = 0·5 mm.; making diameter = 4·5 mm.

Locality.—Jumbo Creek, near Bonanza Mine, Copper River region, Alaska. U.S. Geol. Surv. Loc. 4809.

Horizon.—Upper Trias, Chitistone Limestone, supposed to be Middle or Upper Carnic, therefore comparable with Raiblian (see G. C. Martin, 1916, p. 692).

Material.—Squeezes in various substances from specimens in the collection of the U.S. Geological Survey, and plaster casts taken therefrom in the British Museum, Geological Department. Registered E 21915–21918, E 22178–22180.

Holotype. — Plaster cast E 22178 and its original at Washington.

Relations.—The most striking feature in the fossils (as interpreted from the squeezes) is the hollow that in nearly every radius of every specimen occupies the position of the radial ridge-groups. At first, this suggests a radial triangle; but closer inspection shows that crenellæ exist all round the periphery, and in rare cases, as in the right upper radius of fig. 14, the radial ridge-groups still remain. It appears as though these structures were of looser texture than usual, and so were easily worn or broken away, leaving as a rule obscure traces or even a mere hollow, as in the left upper radius of fig. 14. This last appearance seems (on the evidence of the squeezes) to be the most characteristic, and though it is not in the strict zoological sense a diagnostic character, it may be regarded as distinguishing what Prof. H. S. Williams (October 1917) has called a 'metamorphic species.'[1] The visible character of such a species is directly due to certain physical, mechanical, or chemical conditions of fossilization or metamorphism; but for it to have any systematic value, it must be indirectly due to some feature in the gross or minute anatomy. That feature may have been invisible until made visible by the extraneous forces, which act as do the differentiating reagents of the laboratory.

[1] 'Nuculites from the Silurian, &c.' Proc. U.S. Nat. Mus. vol. liv, pp. 27–58.

Apart from this peculiar character, the species differs from other known Triassic species. Those which resemble it in the crenelation of the suture and in the absence of a radial triangle have petal-floors depressed, and not flush as here. In *I. trechmanni*, which has flush petal-floors, the peripheral crenellæ are fewer and are generally confluent.

ISOCRINUS GRAVINÆ, sp. nov. (Fig. 15, p. 248.)

Transverse section a slightly excavate star with rounded angles. Normal joint-face with lumen small (obscure, say 0·5 mm.); central area merging into adradial crenellæ; petals narrow (4·4 mm. long, 1·6 mm. at greatest width, giving ratio of 0·36), their floors depressed, with a greatest width approximately one-third of the width of the petal (actually 0·6 mm.); adradial crenellæ, after the obscurely formed adcentral crenellæ, are about 10 on each side, regularly corresponding, 0·5 mm. long; peripheral crenellæ estimated at 5 (the ends of petals are broken); a well-marked radial triangle with surface rising gently towards the radius in its outer (acentral) region.

Approximate measurements:—IR = 4·9 mm.; $r = 3·1$ mm.; reëntrant angle = 0·7 mm.; making diameter = 8·7 mm.

Locality.—Cove 3 miles north of Dall Head, Gravina Island (S.E. Alaska).

Horizon.—Upper Trias, supposed to be Lower Noric (see G. C. Martin, 1916, p. 700).

Material.—Squeezes in various substances from specimens in the collection of the U.S. Geological Survey, and plaster casts taken therefrom in the British Museum, Geological Department. Registered E 21913, E 22181–22182. An obscure squeeze, E 21914, indicates that a more broadly petaloid *Isocrinus* occurs in the southern arm of this cove.

Holotype. — Plaster cast, E 22181 and its original at Washington.

Relations.—A very distinct form. In the large radial triangle and narrow petals it approaches a true *Pentacrinus* much more closely than does *Isocrinus argenteus*, and, unlike that species, it has no radial ridge-groups.]

A radial triangle is slightly developed in *Isocrinus propinquus* and is well marked in an undescribed *Isocrinus* in Dr. Wanner's material from the Upper Trias of Timor. All these species are thereby distinguished from *I. trechmanni*.

There seems no doubt, then, as to the specific independence of these New Zealand fragments, and I can find no name more fitting to be associated with them than that of their collector, who has thrown so much light on the real and alleged Triassic deposits of New Zealand.

[November 30th, 1918.

9. Jurassic Chronology: I—Lias. By S. S. Buckman, F.G.S.

(Read June 6th, 1917.)

[Plates XXVI–XXXI.]

Contents.

I. Introduction.

During the last few years[1] I have been engaged to examine a series of ammonites and brachiopods—some thousands of specimens—collected by the officers of the Geological Survey of Scotland in the islands of the Inner Hebrides off the west coast of Scotland—Mull, Skye, Raasay. As the thickness of these Oolite-Lias deposits is very considerable and specimens are in many places numerous, the faunal sequence is often observable to great advantage; and, as new faunal elements have been disclosed in some cases, the Oolite-Lias chronology requires a certain amount of elaboration and revision. By the kind permission of the Director of the Geological Survey I am allowed to give an abstract of certain results. These data, when compared with those which have been gradually accumulating about other districts, throw an interesting light on the faunal sequence in certain strata, and, though admitting that all suppositions are not yet proved, I venture to offer to the Society an epitome of evidence and surmise with the idea of drawing the attention of other workers to the particular points about which further investigation is desirable.

[1] This paper was commenced in the winter of 1914–15.

The classical paper on the Scottish area is that by J. W. Judd.[1] He proposed the terms 'Scalpa Sandstone' and 'Pabba Shales,' and, though working under great difficulty, showed considerable acumen in his zonal classification: he recognized the presence of the zones of *humphriesianum*, *murchisonæ*, *spinatus*, *margaritatus*, *ibex*, *jamesoni*, *armatus*, *oxynotus*, *semicostatus*, and *bucklandi*.

A more elaborate faunal sequence is put forward at the present day, as shown by various chronological lists which have been published by the present writer, for instance:—

1898. 'Jurassic Time' Q. J. G. S. vol. liv, p. 442.
1901. 'Hom. Brach.' Proc. Cotteswold F. C. vol. xiii (4), App. II, p. 265.
1910. 'Jurassic Strata' Q. J. G. S. vol. lxvi, p. 86.
1910–13. 'Yorkshire Type Ammonites' i, p. xvi; ii, p. x.
1915. 'Pal. Class. Jur. Rocks'; 'Geol. Whitby' 2nd ed. Mem. Geol. Surv. 1915, chap. v, p. 60.

The tables in the two last-named publications may be taken as a basis of reference. But the excellent results obtained by Mr. W. D. Lang,[2] by most painstaking work on the Dorset Coast, show that still further elaboration is required. The same is the lesson taught by the Scottish deposits. I propose to illustrate and compare these results with each other, and with details from intermediate areas.

The present paper is entitled 'I—Lias' to indicate that it is the first of a proposed series, to be followed, I hope, by further papers on the Oolites so as to complete the Jurassic Chronology on the same lines. The present paper gives the information about the Lias by working downwards from younger to older deposits, because that presents the different sections of the strata in continuous orderly sequence. Strictly speaking, then, this series of papers should have commenced with the latest rocks of the Jurassic; but, as I am not prepared with their details, the sequence in the papers and that in the series must remain at variance—a technical blemish.

One could wish that, for geological and other records, printing and reading were from the bottom of the page to the top, because then results could be placed in their due order of developmental sequence.

For stratigraphical information, palæontological material, and generous assistance, I am very greatly indebted to several kind friends: for Scotland, to Dr. G. W. Lee and other officers of the Geological Survey, Scotland; for Yorkshire, to Dr. F. L. Kitchin, Mr. G. W. Lamplugh, Mr. G. Barrow, and other officers of the Geological Survey, England; for the Midlands, to Mr. B. Thompson; for Somerset and Gloucestershire, to Mr. J. W. Tutcher; for the Dorset Coast, to Mr. W. D. Lang; for varied information, to

[1] 'The Secondary Rocks of Scotland' (West Coast), Q. J. G. S. vol. xxxiv (1878) p. 660.
[2] Proc. Geol. Assoc. vol. xxv (1914) p. 293.

Dr. A. Morley Davies. To all I tender most grateful thanks.[1] For the Yorkshire area and for the South-Western Counties I have also had my own field experience—chiefly in the last-mentioned area.

Part of the following pages may be regarded as an extension of the principle applied with success to sundry brickyard exposures along a line of country—the principle of unlike faunas. Different contiguous exposures show faunas of partly or wholly unlike facies: therefore their deposits are partly or wholly heterochronous—find the sequence. In wider extension three are obviously other factors for consideration—agency of deposition, difference of basin, constituents of the fauna—like must be compared with like. But the following pages show, it is hoped, that the method of work may be extended and justified; and that it may answer both ways—for, as a proved sequence shows the meaning of dissimilar faunas, so dissimilar faunas give reason for expecting heterochronous deposition.

It is fairly evident that geologists have been using the principle of dissimilar faunas in separating strata, without recognizing it—much as M. Jourdain had written prose without knowing the fact. But it is not proposed to pursue the matter further now—it deserves a study to itself—and perhaps a terminology!

II. Yeovilian and Whitbian.

The whole of the Yeovilian and a considerable part of the Whitbian are unrepresented by strata in the Scottish isles: a deposit, about 75 feet thick in Raasay, which I term the Dun Caan Shales, corresponding in date to the post-*moorei* part of the Bridport Sands of South Dorset[2] (early Aalenian), rests non-sequentially on the Raasay Ironstone, which is of the date of the lower part of the Whitby Alum Shale—post-*falciferum* hemera. This non-sequence represents a break of about 700 feet of strata on the evidence of various English localities[3]; and may prove to be very much more when Continental deposits come to be analysed with the same detail.

The chronology of the Yeovilian and Whitbian has been already rather fully particularized in the last two communications mentioned in the list of works on p. 258; but there is reason to suppose a fuller faunal sequence in the former, and (as regards the latter) it seems desirable, on the ground of palæontological uniformity, to class as early Whitbian the bed or beds hitherto regarded as latest Domerian, see Summary, pp. 275, 276.

The attention of investigators should be particularly directed to the sequence of strata on the Whitbian–Domerian border-line—

[1] To Mr. Tutcher my thanks are due for his careful photographic illustrations to the Palæontological Appendix.

[2] Q. J. G. S. vol. lxvi (1910) pp. 60, 61, 64.

[3] *Ibid.* vol. lix (1903) p. 456; 'Geol. Whitby' 2nd ed. Mem. Geol. Surv. 1915, chap. v, p. 75.

the post-*spinatum* pre-*falciferum* deposits. This was a time of earth-movement and local non-sequences: the full succession—perhaps more elaborate than that to be recorded in the Summary—may possibly be made out by taking note of dissimilar faunas.

The strata of the Yeovilian, and, locally, even certain beds of the Whitbian, have until comparatively recent times been classed with the Inferior Oolite Series or as Passage Beds between Lias and Oolite—the dividing-line between Lias and Oolites (or Lias and Passage Beds) being roughly taken along the line of change from clay to sand; but this has been found to vary palæontologically by several hemeræ.[1] Such former association, however, suggests that there may be a more suitable opportunity to discuss these strata in a proposed later communication dealing with the faunal sequence of the Lower Oolites.

III. Domerian.

The Scalpa Sandstone, about 240 feet thick, is in the main of Domerian date; some of the base is earlier. There is no direct evidence for the stratigraphical sequence, but the faunas of the *spinatum* and *margaritatus* dates are present, with that of *algovianum* indicated. There is, however, another remarkable fauna in a distinctive matrix: it yields *Amaltheus lævis* (Quenstedt), in some abundance, some massive Rhynchonellids and other brachiopods. The *Amaltheus*, a Würtemberg species, a very distinct dwarf form, has not hitherto been found in English strata, if my memory serves me truly; the massive Rhynchonellids[2] are quite new to this country; the other brachiopods agree in the main with Domerian species of Yorkshire.

It is suggested, on the principle of dissimilar faunas, that the Scalpa Sandstone shows a new faunal horizon—one post-*margaritatus* pre-*spinatum*—a deposit made during a hemera of *Amaltheus lævis*, well-developed and preserved in Raasay, possibly in part preserved in Yorkshire—it is to be looked for at the junction of the above-mentioned zones—partly, if not entirely, absent from the South of England; but to be found locally on the Continent, possibly in some thickness.

However, with this addition the sequence of Domerian faunas is certainly not complete. This is well shown in a paper by M. J. Monestier.[3] The strata between the Charmouthian and the *spinatum* horizon hitherto placed in the zones *margaritatus*-*algovianum* (Oppel's upper and lower *margaritatus* zones) are separated out by him into three subzones, with, in some cases, further division into upper and lower horizons.

[1] 'Monogr. Inf. Ool. Amm.' (Pal. Soc.) 1890, p. 167.

[2] *Grandirhynchia*, S. Buckman, 'Gen. Jur. Brach.' 1914. Two species figured in 'Brach. Namyau Beds, Burma' Pal. Ind. n. s. iii (2) 1917 (1918) pl. xiii, figs. 5 & 6, and described on p. 228.

[3] 'Zone à *Amaltheus margaritatus*' Bull. Soc. Géol. France, ser. 4, vol. xiii (1913) p. 5.

From his excellent paper I extract the following as a summary of the sequence:—

TABLE I.—FAUNAL HORIZONS OF LOWER DOMERIAN.
(After J. Monestier.)

Subzone *c.*	Upper horizon.	'*Amaltheus gibbosa* Quenstedt.'
	Lower horizon.	'*Seguenziceras algovianum* Oppel.'
Subzone *b.*		'*Cœloceras acanthoides* Reynès'
Subzone *a.*	Upper horizon.	'*Hildoceras boscense* Reynès.'
	Lower horizon.	'*Grammoceras fieldingi* Reynès.'

Monestier (p. 11) gives *Amaltheus lævis* as a constituent of his subzone *c*. Perhaps this is due to local paucity of deposition, for the evidence of Raasay, so far as it goes, is to the contrary; *A. lævis* is from near the top of the Scalpa Sandstone, while the indication of an *algovianum* fauna is near the base some 200 feet lower.

Over a considerable part of England it is possible that all, or nearly all, of Monestier's horizons are not represented, the Domerian beginning with the *algovianum* horizon, or even later than that locally. On the Dorset Coast, however, these lower strata may, perhaps, be found.

The thickness of the Domerian on the Dorset Coast exceeds, according to Day's evidence,[1] that of the Scottish deposits, and very considerably. From the Three Tiers to the Marlstone of the Junction Bed, inclusive, there are 364 feet.[2] It is possible that 180 feet of this—the lower part—represents strata missing from the Scottish deposits and from other English localities; for it is permissible to interpret Day's record of *Am. thouarsensis* in the Shell Bed (p. 291) as *Seguenziceras* aff. *algovianum*: this would give about 180 feet from *algovianum* to *spinatum* inclusive, which compares well with about 200 feet of Scalpa Sandstone within the same limits, leaving 180 feet below in which Monestier's pre-*algovianum* horizons may be sought—I have seen something of a *boscense* style with the matrix of the Dorset Coast.

Monestier quotes an *Amaltheus* fauna through all his horizons, and Day gives *A. margaritatus* through about 330 feet of strata on the Dorset Coast. It is to be regretted that investigators have too often placed all the species of *Amaltheus* under one name: for with careful discrimination much information might have been gained as to their horizons, with great advantage to correlation work.[3] But this range of *Amaltheus*, followed by its allied genus *Paltopleuroceras*, induces the reflection that the strata yielding these Amaltheidæ ought alone to be classed as Domerian—the age of Amaltheids.

In certain cases, then, the division between Whitbian and

[1] 'Middle & Upper Lias of the Dorset Coast' Q. J. G. S. vol. xix (1863) pp. 283–85.

[2] *Amaltheus* has been found some 2 feet below the lowest tier, W. D. Lang, Proc. Geol. Assoc. vol. xxv (1914) p. 329.

[3] Species of *Amaltheus* are enumerated in 'Yorkshire Type Ammonites' 1911, p. 25 d; but this by no means exhausts the series.

Domerian would fall in the upper part of the Marlstone. The highest layer of Marlstone on the Dorset Coast —the *serrata* bed [1] with Harpoceratoid ammonites,[2] may, on the principle of dissimilar faunas, be expected to be of different date from the Transition Bed of the Midlands with *Tiltoniceras* and peculiar Dactyloids—a bed of lithic condition similar to decomposed Marlstone. Removal of these two horizons to Whitbian would certainly make for greater zoological uniformity, see p. 276.

The following comparative table of Scottish and English Domerian may be given.

TABLE II.—DOMERIAN SEQUENCE.

Dates. Hemeræ.	Strata. Raasay.[1]	Yorkshire.[2]	Cheltenham District.[3]	N. Somerset.[4]	Dorset Coast.[5]
7. *spinatum*	×	3–11 ?	C.	S.	Base of Junction Bed.
6. *lævis*	×	(12–21) ?			
5. *gibbosa*	×	22–26	C.		*Margaritatus* Bed +
4. *algovianum* ...	×	27–34			Shell Bed +
3. *acanthoides* ...					
2. *bcscense*.........					(Strata about the 3 Tiers) ?
1. *fieldingi*.........					

[1] The Scalpa Sandstone.
[2] The numerals refer to beds in 'Geol. Whitby' *op. cit.* pp. 73, 74.
[3] The *algovianum* fauna is not known from the Cheltenham district; but is recorded by Wright from Oxfordshire—Chipping Norton.
[4] Even the *spinatum* deposit is often missing.
[5] See Day, *loc. cit.* and S. S. Buckman, *op. cit.* p. 66. Intermediate beds cannot be placed on present evidence. A much fuller faunal sequence than is here recorded between *spinatum* and *algovianum* seems quite likely.

[× Fauna present, position surmised. C., S., Beds in known sequence.]

For a further illustration, see fig. A, p. 265, and for further details the remarks on that page.

IV. CHARMOUTHIAN.

Some small portion of the lower part of the Scalpa Sandstone belongs to the Charmouthian; but its main mass is made up of the Pabba Shales, 600 feet thick in Raasay, 700 feet in Skye.[3] They are richly ammonitiferous, especially in the lower 400 feet or so

[1] 'Jurassic Strata' Q. J. G. S. vol. lxvi (1910) p. 65, bed *i*.
[2] The species figured by Wright, 'Monogr. Lias Amm.' (1884) pl. lxxxi, figs. 4–6 as '*Harpoceras radians*, Upper Lias Shale, East Brent Knoll, Somerset' bears a label in Dr. Wright's handwriting 'Down Cliffs, Charmouth,' and is from the top bed of the Marlstone of the Dorset Coast. It well represents the forms here alluded to: they require to be worked out and named. There is perhaps some connexion with *Am. pseudoradians* Reynès, 'Géol. Pal. Aveyron.' 1868, pl. i [*bis*], fig. 4. Wright's specimen is in the British Museum (Natural History) No. C. 2200.
[3] These thicknesses were communicated to me by Dr. Lee.

representing the so-called zones of *armatum-raricostatum*, where they disclose a quite unexpected sequence of events. Concerning the upper part of the Charmouthian they do not give much information; but here Mr. Lang's detailed researches on the Dorset Coast come in.

Owing to the number of faunal horizons disclosed by the English and Scottish strata, it becomes necessary to divide the Charmouthian; and it is at once noticeable that in the upper part the Ammonite families Liparoceratidæ and Polymorphidæ are dominant, in the lower part the families Deroceratidæ and Echioceratidæ. But such division into two parts would leave the upper portion unduly large, while division into three parts gives better balance. In the upper third the Liparoceratidæ are the dominant feature with the Polymorphidæ subservient; in the middle third the position is precisely the reverse; while in the lower third the Deroceratidæ and Echioceratidæ keep alternating in their domination. Therefore it is proposed to divide the Charmouthian into three ages, named respectively Hwiccian, Wessexian, and Raasayan. These terms are governed as to their limits, not by stratigraphy, but by faunal constituents; and there should be no necessity to change them if future discoveries show the advisability of small additions to, or subtractions from, the stratigraphical units now respectively assigned to them.

Perhaps no author has proposed, and, in the light of present knowledge, perhaps no author can propose stratigraphical or chronological terms with fixed limits: non-sequences and the progress of palæontological discovery are against such results. Detailed investigation has often revealed that the upper and lower limits of a given stratigraphical term used by the same author really vary from area to area to the extent of the deposits made during several hemeræ in each case. Then the limits require corresponding adjustments; but to alter the names whenever small adjustments are made would produce a confusing multiplicity of terms for what is substantially the same thing. It is too much to expect that limits can be exactly fixed, even on the basis of dominance of certain Ammonite families: future discoveries may spring surprises on us. It is unlikely that the remarkable sequence disclosed at Raasay (Raasayan, p. 267) with the large adjustment which it involves will be the only discovery of its kind.

(1) Hwiccian.

The lower scarp of the Cotteswolds and the outliers which stand as sentinels along the valleys of Severn and Avon in the counties of Gloucester and Worcester show some fine developments of strata earlier than the Domerian. The Hwiccas,[1] whose country

[1] 'The Hwiccas ... the people of Gloucester, Worcester, and part of Warwick .... the old Diocese of Worcester before Henry the Eighth formed the sees of Gloucester and Bristol. The Bishops' Dioceses are generally the best guides to the boundaries of old principalities.'—(E. A. Freeman, 'Old English History' 3rd ed. 1873, p. 82.)

exhibits these deposits, may well give their name to the age—Hwiccian: it is the age when the Liparoceratidæ were dominant and the Polymorphidæ subservient. The following Table III gives an interpretation of the evidence in Scottish and English areas.

TABLE III.—HWICCIAN: SCOTLAND AND ENGLAND.

Dates.	Strata.				
Hemeræ.	RAASAY.	YORKSHIRE.[1]	GLOUCESTERSHIRE.[2]	N. SOMERSET.[3]	DORSET COAST.[4]
9. *Oistoceras*		3			130. } *Oistoceras* 129. } *+bechei.*
8. '*henleyi*'					126. Involute *Androgyn. henleyi*-type; *davœi.*
7. *davœi*					125. *davœi.*
6. (3rd capricorn).	Capricorns, base of Scalpa Sandst.	5			
5. (2nd capricorn).		6	Capricorns, Pilley, Leckhampton.		
4. *latæcosta* (1st capricorn).		×7 (*Androg. maculatum, Androg. heterogenes*)	Dudbridge. (*Androg. latæcosta*)	Radstock; Bath. (Evolute *Androg.*)	124. } *Androg.* 123. } *latæcosta* 122. } group.
3. *Beaniceras* ...		×7 (*Beaniceras*)	Hewlett's Road (Yellow Lias); Stow-on-Wold. (*Beaniceras*)	Slopes of Dundry. (*Beaniceras*)	121. [*Beaniceras*;] *Liparoceras.*
2. *carinatum*			Leckhampton? Hucclecote? (Stout *Acanth.*)		120 *b.* [*Beanic.*?] *Acanth. carinatum*; *Ac.* spp.; *Liparoc.*
1. *cheltiense*		×7 (*Lip. heptangulare*)	Charlton Kings; Dumbleton, etc. (*L. cheltiense*)	Radstock; Dundry. (*Lip. zieteni*)	120 *a.* *Liparoc.*

[1] The numbers refer to beds in 'Geol. Whitby' 2nd ed. Mem. Geol. Surv. 1915, p. 69; the strata are about 155 feet thick, Bed 7 being 35 feet.

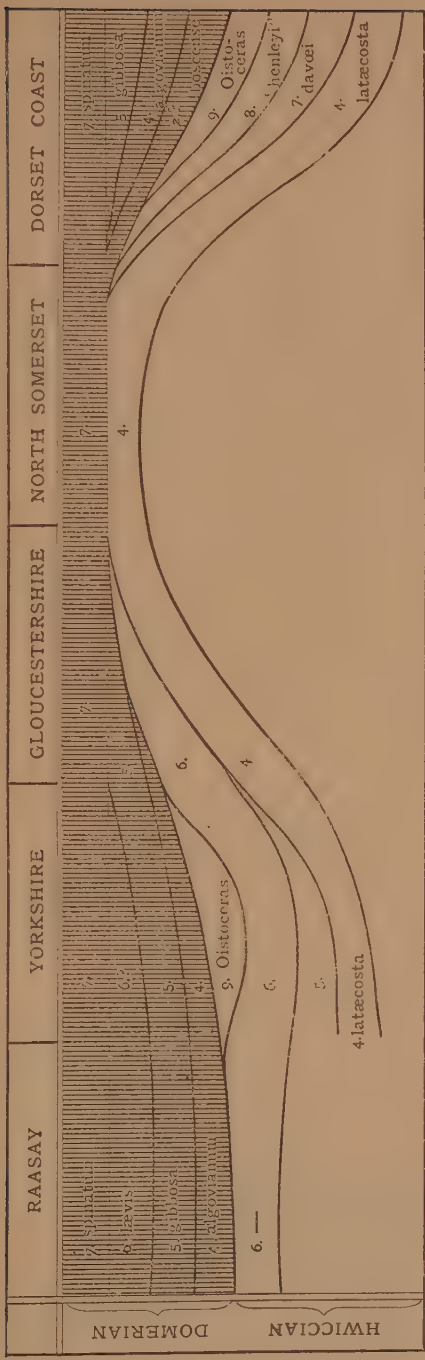
[2] Specimens collected by my father, and personal observations.

[3] Mr. J. W. Tutcher's information.

[4] W. D. Lang, Proc. Geol. Assoc. vol. xxv (1914) p. 293; the numbers are those of his beds. In regard to this and the following tables, my best thanks are due to Mr. Lang for the great pains that he has taken to supply me with information, sending MS. notes of later researches and submitting specimens—my identifications are in square brackets. Since this paper was read he has published some of these MS. notes—'The *Ibex*-Zone' Proc. Geol. Assoc. vol. xxviii (1917) p. 31.

[× Fauna present, position surmised.]

Fig. A. *Diagram illustrating the faunal sequences in the Domerian-Hwiccian.*



The accompanying diagram (fig. A) shows the faunal sequences, and non-sequences, in the Domerian and Hwiccian of the areas under consideration. No account is taken of the thicknesses of strata; it is only a faunal record; but it becomes a stratigraphical illustration of the position of affairs when the concluding strata of the Domerian were deposited.

The datum-line is 7 Domerian (*spinatum*) proved in all areas.

The movement of the Mendip axis of North Somerset is quite obvious. Its influence apparently extended to Gloucestershire. On the Dorset Coast, though the Domerian strata are especially thick, there are two more non-sequences, due possibly to movement of the Weymouth anticline. The last of these, the pre-*spinatum* one, which presumably coincides with the lack of the *lævis* zone of Raasay, is particularly interesting. The base of *spinatum* has Blue Lias pebbles, the date of which it would be interesting to determine. If, as has been supposed, the pebbles are from early Domerian beds,[1] which happen to be about

[1] Q. J. G. S. vol. lxvi (1910) p. 82.

160 or 200 feet below, this indicates a movement of the Weymouth anticline to about that extent in order to expose the bed to denudation. But the pebbles may be very much earlier, and the movement may have been considerably greater.

(2) Wessexian.

The name for this age is taken from the Old English kingdom of Wessex, which embraced the South-West of England, though its boundaries diminished and enlarged from time to time, varying more than the boundaries of a stratigraphical term—yet, like a generic title, it kept the same name. The Dorset Coast, Somerset, and Gloucestershire, were all part of it at one time, and all this area shows strata of the age. The Radstock district in Somerset has the strata thinly developed, and therefore not lending themselves

TABLE IV.—WESSEXIAN: SCOTLAND AND ENGLAND.

Dates.	Strata.				
Hemeræ.	RAASAY.[1]	YORKSHIRE.[2]	CHELTENHAM.[3]	RADSTOCK.[4]	DORSET COAST.[5]
10. *valdani*	?		×	R.	119 *b*. *Ac. valdani* group.
9. *ibex*		× (*Tragophylloceras* fauna only)	× (*T. ibex* fauna only)	R.	119 *a*. } 118 *c*. } *A. maugenesti* group. *T. ibex* & *wechsleri*.
8. *ellipticum* ...					118 *b*. *Ac. ellipticum* group.
7. *bronni*			× *U. bronni* + fine-ribbed *U. jamesoni* form (Wright).		{ 118 *a*. *U. bronni* forms [and fine-ribbed *Uptonia*.] 115 *b*. *U. bronni* forms.
6. *Platypleuroceras*.	R.	8		×	{ 115 *a*. [*Platypleur*.] 113. [*Platypleur*.?]
5. *trivialis*		8			111. [*Polym. trivialis* group.]
4. *jamesoni*	R.	9		R.	
3. *pettos*					110? [*C. pettos*, *C. grenouillouxi*.]
2. *peregrinus* ...					108. [*Polym. peregrinus*? Haug].[6] Deroceratid.
1. *Phricodoceras*.		11	× J. Buckman Coll.	R.	105. *Phricodoceras*.

[1] R. beds in position; about 30 feet separates them.
[2] See former Table. About 120 feet involved.
[3] As in Table III (p. 264) and in Wright's records.
[4] As in former Table. R.=beds in known sequence; ×=fauna present, position surmised.
[5] See former Table.
[6] *Ægoceras polymorphus* Wright, pl. xl, figs. 1–3, cited by Haug as near to his species.

[To face p. 267.]

TABLE V.—RAASAYAN: SCOTLAND AND ENGLAND.

Dates. Hemeræ.	Strata. RAASAY,[1] about 400 + feet.	YORKSHIRE,[2] about 85 feet.	MIDLANDS,[3] about 10 feet.	SOMERSET (RADSTOCK),[4] about 5 feet.	DORSET COAST,[5], about 45 feet.
7. *leckenbyi*	Beds on Hallaig shore with large Derocerates.	Beds 13–16 with large Derocerates.		The Gastropod Beds (the *armatus* bed) with large Derocerates.	'Bed 105. *Armatus* Limestone, *Deroceras pugnax?* S. Buckm., *D.* aff. *leckenbyi*' [*D. leckenbyi* (Wright) pl. xxx, figs. 1–3]. 'Bed 104 *Armatus* Clay.' 'Bed 103. Hummocky Limestone.' [*D.* aff. *lorioli* Hug sp.]
6. *aplanatum*	Loc. 12, 13. Beds with carinati-sulcate *Echioceras*.	Bed 18. 'The Upper *Coneybearei* bed' with *E. aplanatum*.			[No evidence for these two faunas and no room for them.
5. *macdonnellii*	Loc. 10 *a*–11. Beds with degenerate *Echioceras* of *macdonnellii* type.	Bed 20. Shale with *Echioceras macdonnellii*.			
4. *raricostatoides*.	Loc. 7–9. Beds with mainly crassicostate *Echioceras*.		Absent.	The faunas of these three horizons are found in derived condition in the '*armatus* bed,' ['with much phosphatic matter. Undisturbed portions of the beds are left at a few places—these consist of thin limestones and shales.'—J. W. T.].	Bed 102. [Crassicostate *Echioceras*.] 'Bed 100.' [c. *E.* cf. *boreale*.] [b. *E.* like above, but more strongly costate.] [a. *E.* cf. *rhodanicum*, *E. gracile*, *E. costidomus*.] 'Bed 99. Watch Amm. Stone' [*E. microdiscus* and a crassicostate species]. 'Bed 98' [*E.* cf. *costidomus* (crushed)].
3. *bispinigerum*	Loc. 4–6. Beds with Rhynchonellids, *Deroceras anguiforme* and *Deroceras* of the *armatum* type.	[The type of *Am. miles* came from Whitby.] [The type of *Am. armatus* came from Whitby.]		No evidence at Radstock for the *bispinigerum* fauna nor for the *densinodus* – *subplanicosta* faunas below.	'Bed 96 [b]. 11′ below bed 99.' [*Deroceras miles*.] '[a] 12′–14′ below 99' *Deroceras armatum*]. 'Bed 94. 15′ below 99' [*Deroc. bispinigerum* sp. nov. See Palæont. App. p. 302].
				SODBURY, GLOUCESTERSHIRE.[6]	
2. *subplanicosta* (*densinodus*).	Loc. 3. *Deroc.* (*Microc.*) cf. *densinodus* (Wright). Loc. 2. *Deroc.* (*Microc.*) aff. *obsoletum* (Blake), *Bifericeras subplanicosta ?*, *B. vitreum ?* (Simpson).	Bed 23. *Amm.* of *subplanicosta* type. *Deroceras obsoletum* (Blake) = *Am. densinodus* auctt. *Deroceras nodoblongum*.	'*Armatus* zone. *A. densinodus* (several spp.), *A. muticus*, *A. subplanicosta*, common.'	'Thin shale with a few limestone bands 30 feet. *Am. densinodus ?*'	'Bed 93' [Ammonites of *densinodus* and *subplanicosta* types.]
1. 1st *Echioceras*.	Loc. 1. *Deroceras obsoletum*, *Echioceras*.	[Bed 23.] '*A. densinodus* [*obsoletus*] is plentiful in a band about 2 feet above [*A. raricostatus*]' Tate & Blake, p. 77.	'*Raricostatus* zone. *A. densinodus*, *A. raricostatus*.'	'Pyritous limestone and shale 2 feet. *Amm.* aff. *armatus*, *Amm. raricostatus*.'	'Bed 92. *Oxynotus* Bed' [*Am. obsoletus* Blake (*non* Simpson) sp.]. 'Pyritized *Oxynoticeras*' [?derived].

[1] Fuller details will be given in a report to be published by the Geological Survey. The 'Loc. 1–13' are places from which collections were made by the geologists of the Scottish Survey in ascending the Allt Fearns Valley, and they show the faunal sequence through about 300 feet of strata. See also 'Yorkshire Type Ammonites' ii (1914) p. 96 d.

[2] 'Geol. Whitby' 2nd ed. Mem. Geol. Surv. 1915, p. 70.

[3] B. Thompson, 'Geol. G. C. Ry.' Q. J. G. S. vol. lv (1899) p. 71.

[4] Information from Mr. J. W. Tutcher and personal observations.

[5] W. D. Lang, Proc. Geol. Assoc. vol. xxv (1914) p. 321, and see remarks, Table III, footnote 4 (p. 264).

[6] S. H. Reynolds & A. Vaughan, 'Jur. South Wales Line' Q. J. G. S. vol. lviii (1902) p. 727.

very rapidly to the detailed sequence now asked for; but the deposits are very fossiliferous and especially ammonitiferous.

This is the age when the Polymorphidæ held chief position, while the Liparoceratidæ were inferior in importance.

Table IV (p. 266) gives the evidence in various areas. A presumed faunal repetition of *Uptonia* (*jamesoni* and *bronni*) seems to be the only method of reconciling this evidence. Such faunal repetition is, however, so much in accord with what Raasay shows in lower beds (see Table V) that the solution seems quite possible. Mr. Lang has also recorded faunal repetition in the case of series of *Acanthopleuroceras* in the Hwiccian and Wessexian of the Dorset Coast, as this and the preceding table show.

(3) Raasayan.

The Scottish evidence in this case is excellent and most important. The result is to show that in the strata hitherto assigned to the *armatum-raricostatum* zones the sequence is much more complicated. There are:

7. Upper *Deroceras* horizon.
6. }
5. } Upper *Echioceras* horizons—three stages.
4. }
3. Lower *Deroceras* horizon.
1, 2. *Subplanicosta* and Lower *Echioceras* horizon—possibly two stages, possibly more, see p. 268.

The Scottish deposits show faunal repetition and faunal alternation of *Echioceras* and *Deroceras*, thus giving the clue to the correlation of the strata in other areas. The available evidence is brought together in the accompanying Table V; more precise details about the lower horizons would be desirable, and further investigation in Raasay may be expected to furnish them.

The great thickness of the Scottish strata—five, ten, and eighty times as thick as the English deposits—is the chief factor in displaying the sequence. Thus it will be seen that, between the *armatum* zone of the Midlands and that of Radstock, hitherto thought to be isochronous, the Scottish deposits exhibit a thickness of some 300 feet of strata.

When the English strata are compared with the Scottish, it will be noted that, although no one locality shows the full sequence, yet all put together prove the Scottish sequence. It is evidently the same on the Continent—the Rhone Basin, Freiburg Alps, Bavaria, Würtemberg, Hierlatz, contain to some extent heterochronous deposits with dissimilar faunas. Each area lacks something; but, when all are placed together, they are seen to supply one another's deficiencies, and to make up the sequence of Table V. Bavaria lacks what Würtemberg has, and supplies in part what Würtemberg lacks; and so with the other Continental areas.

There is reason to suppose that at the beginning of the Raasayan considerable earth-movement took place producing various local non-sequences—a legacy from Deiran times (see p. 273 and

fig. B, p. 272). As a consequence it may be expected that the faunal sequence in early Raasayan was more complicated than that shown in Table V. The Sodbury evidence gives the association of '*Am.* aff. *armatus*' and '*A. raricostatus*' [an armatoid and an *Echioceras*] below the *densinodus* [*obsoletum?*] horizon. The Midlands, according to Mr. Thompson's evidence, show the second at a lower horizon than various armatoids which he associates with *Am. subplanicosta.* Cheltenham has a very definite *subplanicosta* horizon, and it is below this that various armatoids occur. A consideration of these points suggests that, instead of the two horizons of the Table, there may be three if not four in the following descending order:—

(*d*) *subplanicosta.*
(*c*) *obsoletum (densinodum).*
(*b*) armatoids.
(*a*) Echiocerates.

Attention to this point would be desirable. Ammonites are abundant, but small. They have not yet been examined in a sufficiently critical manner—a very long task; in many cases their identification with already named species is open to much doubt.

The faunal repetition in the Raasayan begins to make many things clearer. For instance, it is now possible to understand the absence of large *armati* from the Midlands; and the very remarkable number of species of *Echioceras.* The list in 'Yorkshire Type Ammonites' (p. 96 c, 1914) enumerates 44 species, and is by no means exhaustive. As the product of development at intervals during a very long period of time, they are much more understandable than as the product of one date; and, as the outcome of repetitive series evolving on parallel lines, the frequent similarity but not identity in the Echiocerata is explicable.

V. Sinemurian.

The Scottish deposits are not rich in Ammonites; but there is evidence for the sequence of certain faunas, while loose blocks on the Hallaig shore of Raasay indicate the presence of others. The evidence is instructive when compared with that of English localities, especially with the detailed work done by Mr. Lang on the Dorset Coast.

The great increase which the Scottish deposits have proved in the faunal phases of the Raasayan might have been anticipated from other localities, if strict attention had been paid to dissimilar faunas. Now, in the Sinemurian, the case may, perhaps, be reversed: by paying attention to faunal dissimilarities it is hoped to anticipate that full faunal sequence which may some day be proved in a thick deposit.

With increase of horizons the need for division of the Sinemurian seems to be great. It has been felt already. Choffat has divided it into Upper, Middle, and Lower Sinemurian,[1] and this

[1] 'L'Infralias & le Sinémurien du Portugal' Comm. Serv. Geol. Port. v (1903) pp. 54–106.

seems to fit the Ammonite development more satisfactorily than a division into two parts. Here it is proposed to adopt something of the same divisions, styling them Deiran, Mercian, and Lymian.

(1) Deiran.

This is the age when the gerontic phase of the Arietidæ was in full development: it is the period of the oxycone Arietids. Its strata are perhaps more developed in Yorkshire than in other English areas; and it takes its name from Deira, the ancient kingdom of which Yorkshire formed a considerable part.

The sequence of faunal horizons is suggested in the following table.

TABLE VI.—DEIRAN.

Dates.	Strata.				
Hemeræ.	Raasay.	Yorkshire.[1]	Cheltenham District.	Somerset.	Dorset Coast.
8. (*lymense*)? ...	No details nor fauna at present.				(×)
7. *Radstockiceras*[2]				Radstock, north of Mendips.	
6. *Gleviceras*[2] ...			Folly Lane, Cheltenham (lower part).		(×)
5. *polyophyllum* .		1? ×	Vale of Gloucester. ×		
4. *oxynotum*			Lansdown, Cheltenham.		
3. *biferum*			Aston Cross, Tewkesbury. ×	Canards Grave, south of Mendips.	
2. *simpsoni*		2			
1. *Gagaticeras* ...		3			

[1] 'Geol. Whitby' 2nd ed. Mem. Geol. Surv. 1915, p. 67.
[2] See Appendix III, Palæontology, pp. 287, 289.
[× Fauna present, position surmised. (×) Fauna present, supposed to be derived and redeposited in Raasayan (Table V, Bed 92): Mr. Lang, however, suggests paucity of sediment.]

The Deiran seems to have been a time of much earth-movement and consequent non-sequences, with the result that there is little correspondence of fauna in different English areas. This means that the sequence given is based mainly on supposition.[1]

The certain evidence is the sequence *Gagaticeras–simpsoni* in Yorkshire with *polyophyllum* presumably later; the sequence *oxynotum–Gleviceras* in Gloucestershire with *biferum*, it is reasonably certain, earlier than *oxynotum*. There is no definite correspondence here to work upon, and other areas give no help as they show other dissimilar faunas.

It is here suggested that the Yorkshire *Gagaticeras–simpsoni* strata are earlier than the Gloucestershire deposits.

The position in the faunal sequence of the *polyophyllum* horizon

[1] See further remarks in Appendix III, Palæontology, p. 310.

(*Oxynoticeras polyophyllum* Simpson sp., 'Yorkshire Type Ammonites' 1909, No. 8) may be worked out on theoretical grounds. If it were placed immediately above *simpsoni*, then the Yorkshire strata would be in sequence; but the biological features of *O. polyophyllum* seem certainly to suggest that it is a derivative of *O. oxynotum* with a suture-line of the same pattern, but details somewhat more elaborated, and with ribbing greatly intensified (renewed costation). In that case it should occur later than *O. oxynotum*, and, as there is no stratigraphical evidence to go upon, it seems advisable to work upon the basis of the biological interpretation. This, however, involves a theory of a non-sequence in the Yorkshire Deiran deposits, and the multiplication of non-sequences is inadvisable unless there be some evidence.

The sequence thus suggested for the noticeably dissimilar oxycone faunas of the different areas makes Yorkshire to show early Deiran deposits with a middle Deiran fauna separated by a break; Gloucestershire, to which the Midlands may be joined, to show middle Deiran faunas with, perhaps, a break in some localities due to removal in places of deposits of *polyophyllum* date: this would account for local appearances and absences of the species in this area; Somerset north of the Mendips to show late Deiran fauna, with little deposit and certainly a good deal of redeposition. Dorset shares with Gloucestershire an oxycone fauna of *Gleviceras* date; but its special form, *O. lymense*, is not found in the other British areas, so far as I am aware. Both these forms are presumably derived and redeposited in Raasayan strata; for, if *O. lymense* were indigenous in Bed 92, it ought to have been found in the Raasayan deposits of other areas. The supposition, then, is that a *lymense* horizon is the latest phase of Deiran.

Much support for the general conclusions here advanced about the dissimilar faunas of the Deiran horizons may be found in Continental works: the Rhone Basin (Dumortier) shows only ammonites of the horizons *Gagaticeras*, *Gleviceras*, and *Radstockiceras*—those of the other horizons are lacking, for the examples figured as *A. oxynotus* by Dumortier are species of about the *Gagaticeras* horizon; Würtemberg (Swabia, Quenstedt) shows the *oxynotum* and *biferum* faunas certainly, doubtfully the *Gleviceras* fauna, but no fauna of the others.

Thus Gloucestershire and the Midlands are to be bracketed with Würtemberg so far as the *oxynotum* fauna is concerned, and are separable from other English areas; Radstock, with its varied and remarkable oxynotes, agrees with the Rhone Basin; it shows special forms not yet found in other British areas—the *Radstockiceras* fauna. Yorkshire shows many oxycones which seem to be peculiar to itself: it has little agreement with other English areas or with Würtemberg, but rather more with the Rhone Basin—not, however, on the same basis as Radstock.

Lastly, Dorset shares with Gloucestershire a little, but has *O. lymense* to itself. (For further remarks see fig. B, p. 272, and also p. 273.)

(2) Mercian.

The strata of this date are well developed in Gloucestershire and the Midlands—mainly the ancient kingdom of Mercia. The Mercian corresponds to the catagenetic phases of the Arietidæ (post-tuberculate *Asteroceras* and incoiling phases of *Arietites*). In middle Mercian is a phase of degenerate Arietids which have lost keel and furrows—usually called degenerate Asterocerates. The fauna is very prominent in Yorkshire, and is found in Ireland and in Würtemberg. It is not, however, known from other British localities, with the exception of Pershore (Worcestershire); but the special Pershore degenerate is a species not known from the other localities. On the principle of dissimilar faunas it is reasonable to expect one, if not two, horizons in middle Mercian somewhat later than *obtusum*.

In early Mercian the Barrow-Gurney fauna has its own peculiarities, possibly indicating another horizon. But this cannot be discussed without a consideration of the Ammonites: so it must be relegated to the Palæontological Appendix, see p. 311.

In regard to *Arietites turneri*, Mr. Tutcher is of opinion that it precedes *birchi*,[1] and this would seem to be the position assigned to it by Tate & Blake. It is true that the name *A. turneri* has been very much misused, and that in a pre-*birchi* position there are, as I have reason to think, forms allied to *Arnioceras* with somewhat of an *Arietites* aspect which possibly require separation as a new genus from both. But an explanation on these lines does not satisfy me, where Mr. Tutcher is concerned; faunal repetition on the lines of *Echioceras* of the Raasayan may be more likely. It is evident that a prolonged stratigraphical and palæontological investigation is required to solve the problem.

The following table gives the evidence of faunal distribution and sequence in the Mercian.

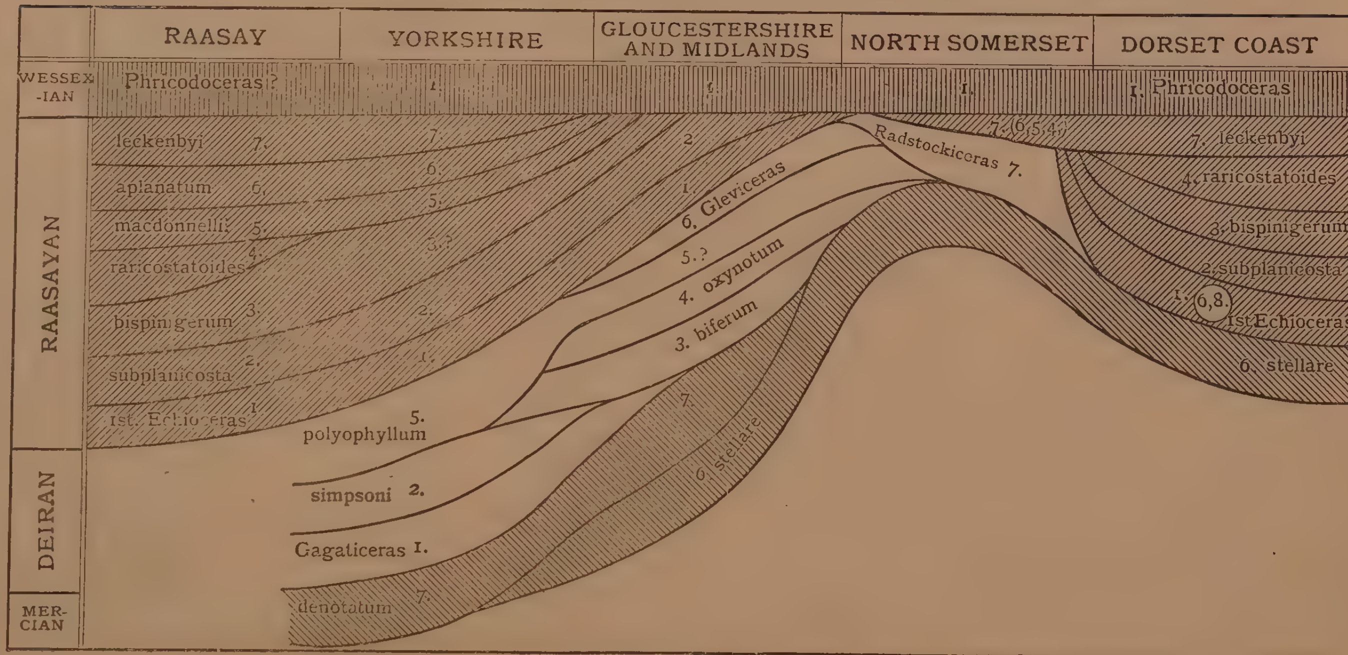
TABLE VII.—MERCIAN: SCOTLAND AND ENGLAND.

Dates. Hemeræ.	Strata. Raasay.	Yorkshire.[1]	Cheltenham District.[2]	Bristol District.[2]	Dorset Coast.[2]
7. *denotatus*		4	×Cheltenham.		
6. *stellare*			×Cheltenham.	Radstock.	88
5. *planicosta*		9		Radstock.	85–87
4. *sagittarium* ...		10	× Pershore.		
3. *obtusum*		10	× Bredon.	Radstock.	83, 84
2. *brooki*	R.				78 82
1. *turneri*	R.		× Bredon.	× Barrow Gurney.	76, 77

[1] 'Geol. Whitby' *op. jam cit.* p. 67. [2] As in previous Tables.

[1] See Appendix I, p. 280.

Fig. B.—*Diagram illustrating the faunal sequences in the Raasayan, Deiran, and Mercian.*



[For '*denotatum*' read '*denotatus*.']

The accompanying diagram (fig. B, p. 272) shows the various earth-movements and denudations which took place during Raasayan and Deiran times, producing many non-sequences. It is constructed on the same principle as the previous diagram (fig. A, p. 265).

The datum-line is 1 Wessexian (*Phricodoceras*), proved in all areas except the Scottish one. Again the continuous movement of the Mendip axis is very noticeable; for, although there are several Raasayan faunas present in North Somerset, yet they are derived almost entirely, shown in the table by bracketing them with 7 Raasayan.

During Deiran times the movements were of several dates not always isochronous in the different areas—hence the fragmentary nature of the deposits and their lack of correspondence. One movement produced obliteration of the early Deiran deposits in Gloucestershire and the Midlands, another the obliteration of the latest deposits. Yorkshire would seem not to have suffered from the first movement, but it did from the last; and, if the position of *polyophyllum* in the sequence be correct, another movement of about middle Deiran time must be postulated: there are traces presumably of a slightly later movement—local obliteration of *polyophyllum*—in Gloucestershire. In North Somerset the first and second movements seem to have had full sway and to have effected complete obliteration, but there was a pause to allow the deposition of 7 Deiran, though the strata then laid down suffered considerably by the latest Deiran movement which continued, with perhaps occasional slight pauses, well into Raasayan times. On the Dorset Coast there would seem to have been continuous movement and penecontemporaneous erosion; at least the result, as I judge it, is that no Deiran deposits were left: there was denudation down to 6 Mercian, but the fossils of some of the later Deiran strata—laid down during short pauses—were swept together and redeposited in early Raasayan.

(3) Lymian.

The strata of this age are well-known and well-developed at Lyme Regis, from which the name may be suitably taken; but, so far as present records allow of interpretation, it seems that they are not complete there. The Lymian is the time of anagenetic and tuberculate Arietids.

The difficulty of ascertaining the number and sequence of horizons in the Lymian is due to the wholly uncritical use of names like *Ammonites bucklandi*. Instead of being a common and universally distributed species as records make out, *A. bucklandi* is a special massive form which I can only be certain of from Keynsham.[1] I suspect the occurrence of another horizon with a fauna of smaller Coronicerates, but whether pre- or post-*bucklandi* has yet to be determined: the placing of it as post-*bucklandi* is a surmise.

[1] See Palæontological Appendix, p. 302.

Mr. Tutcher takes strong exception to the use of *Arnioceras* to indicate a horizon, because it has too wide an extension, ranging, he says, through most of the strata here placed as Lymian. But the Dorset evidence shows *Arnioceras* dominant in a particular set of beds; and, although this may be striking because of the absence of certain preceding strata, yet it is sufficient for the present: there is a post-*Agassiceras* horizon with *Arnioceras* shown at Raasay, and a pre-*birchi* horizon with *Arnioceras* in Dorset. A more suitable name for this faunal horizon must wait until the many species of the genus are better known. It is quite possible that here again may be faunal repetition.

The following table gives the evidence of the various areas:—

Table VIII.—Lymian: Scotland and England.

Dates.	Strata.				
Hemeræ.	Raasay.	Yorkshire.[1]	Gloucestershire,[2] etc.	Bristol District.[3]	Dorset Coast.[4]
8. *birchi*	×		× Bredon, W.	× Horfield.	75
7. *Arnioceras* ...	R.	Up. *Bucklandi* [*b*].	×	Radstock.	50–72
6. *Agassiceras* ...	R.	{ Up. *Buckl.* [*a*]. Mid. *Buckl.*	× Bredon, W.	Keynsham.	49 ?
5. *gmuendense* ...	×		× Berkeley, W. Mon. pl. iv.	Keynsham.	
4. *vercingetorix* .		Low. *Buckl.* [*c*].	× Fretherne, W. Mon. pl. iii.		(40–47) ?
3. *bucklandi*				Keynsham.	
2. *rotator*				Keynsham.	{ (26–29) ? × Wright, Mon. pl. v, f. 4.
1. *Vermiceras* ...	R.	{ Low. *Buckl.* [*a*]. Top *angulatus*.		{ Keynsham. Sodbury.	21

[1] See R. Tate & J. F. Blake, 'Yorkshire Lias' 1876, pp. 58–62, suggested interpretation.

[2] W., Wright's records in his 'Monograph of the Lias Ammonites' (Pal. Soc.).

[3] Mr. Tutcher's information, and a summary of MS. sections which he has most kindly allowed me to use.

[4] My interpretation of Mr. Lang's records, Proc. Geol. Assoc. vol. xxv (1914) pp. 310 *et seqq.*, and one of Wright's records.

[R. Strata in relative position. × In all cases, fauna present, position surmised.]

The faunal sequence below the Sinemurian (Lymian) I leave in the most capable hands of Mr. Tutcher, who has kindly contributed what is placed as Appendix I, p. 278. He has also given his reading of the lower part of the Sinemurian sequence, as he has observed it in the Bristol district: this, too, I am pleased to record. There are differences in our two accounts; but, as they are records of original observation and research, not statements for a text-book, there is no need to strive for uniformity. Several differences are merely details: he uses trivial names where I employ generic.

There are two main differences: one, his placing of *turneri*, upon which I have already commented (p. 271); the other, his placing, on the evidence of local deposits, a *scipionianum* zone between *Agassiceras* (*sauzeanum*) and *gmuendense*; this I am quite prepared to accept. The omission of the *vercingetorix* horizon was expected: the area under Mr. Tutcher's observation lacks the fauna, so far as my knowledge goes.

With regard to our use of the term *turneri* zone, it has been objected that this term should be employed in the sense and for the strata to which it was originally applied by Wright. This dictum I traverse. I would argue that the zone of *turneri* is determined not by the author, but by the fossil. The zone of *turneri* is the deposit made while *A. turneri* was in existence: it is the deposit of the hemera *turneri*. If a writer misidentifies *A. turneri*, he misnames its deposit *turneri* zone. If a future historian identified Queen Elizabeth as Queen Victoria, and called the Elizabethan Period the Victorian Age, he would not thereby make it so and shackle future writers. The Victorian Age was determined by the time when Queen Victoria lived; and the *turneri* hemera, and the deposit made then—the zone—must likewise be determined by the time when *A. turneri* lived.

As to who is right or wrong in the determination of *Ammonites turneri* I am not yet prepared to argue.

VI. Summary.

The various horizons of the Ages dealt with in this paper may now be brought together in sequence; and a table (Table IX, pp. 276–77) may be given of certain notable areas of Great Britain and the Continent, recording the presence of the faunal horizons in Scotland, the North and South of England, the Rhone Basin (Dumortier), and Würtemberg (Swabia, Quenstedt). The results are interesting, and they suggest that a more extended analysis on these lines might yield some rather striking information. Such analysis may, perhaps, be attempted at some later date.

VII. Conclusion.

This is a sketch, much of it theoretical. Its main purpose is to be a basis for further work, indicating the details and evidence which investigators should look for. Much research is yet necessary to obtain perhaps even an accurate sequence; for it is not claimed that all the sequences are proved: they are offered as interpretations of the present available evidence.

One lesson which may, perhaps, be learnt from this study is that great indeed as is the advantage of collecting specimens *in situ*, yet it is not absolutely essential: in some cases, owing to paucity of sediment and to derivation of specimens, it may even lead to erroneous conclusions. As collecting *in situ* is very often quite impracticable, it may be well to remember that much can be done without it, provided specimens are properly localized. For the

TABLE IX.—GEOGRAPHICAL DISTRIBUTION.

Faunal Horizons.		Areas. West Scotland.	Yorkshire.	Dorset Coast.	Rhone Basin.	Würtemberg.
YEOVILIAN. Age of Dumortierians and Grammoceratids.	9. *moorei*	…	…	×	…	×
	8. *Catulloceras*[1]	…	…	×	…	×
	7. *Dumortieria*	…	×	×	×	×
	6. *Hammatoceras*[2]	…	…	×	×	×
	5. *dispansum*	…	×	…	×	
	4. *struckmanni*	…	×	…	×	
	3. *pedicum*	…	…	…	×	×
	2. *eseri*[2]	…	…	…	×	×
	1. *striatulum*	…	×	×	×	×
WHITBIAN.[3] Age of Dactyloids and Harpoceratids.	11. *variabilis*	…	×	…	×	×
	10. *lilli*	…	×	…	×	×
	9. *braunianum*	…	?	…	×	
	8. *fibulatum*	…	×	…	×	
	7. *subcarinata* — *Hild. bifrons* fauna	×	×	×	×	×
	7. *subcarinata* — *Frechiella subcarinata*[4]	…	×	…	×	
	6. *pseudovatum*	…	×			
	5. *falciferum*	×	×	×	?	?
	4. *exaratum*	×	×	…	×	
	3. *tenuicostatum*	?	×	?	…	?
	2. *acutum*	…	?	…	…	?
	1. Harpoceratoid	.	…	×		
DOMERIAN. Age of Amaltheids. See p. 260.	7. *spinatum*	×	×	×	×	×
	6. *lævis*	×	?	…	…	×
	5. *gibbosa*	×	×	×	?	×
	4. *algovianum*	×	×	×	?	×
	3. *acanthoides*[5]					
	2. *boscense*[5]	…	…	?		
	1. *fieldingi*[5]					
HWICCIAN. Age of Liparoceratidæ. See p. 263.	9. *Oistoceras*	…	×	×	…	×
	8. '*henleyi*'	…	…	×	…	?
	7. *davœi*	..	…	×	×	×
	6. (3rd capricorn)	×	×			
	5. (2nd capricorn)	…	×	…	?	
	4. *latæcosta* (1st capricorn)	…	×	×	×	×
	3. *Beaniceras*	…	×	×	?	×
	2. *carinatum*	…	…	×	×	×
	1. *cheltiense*	…	×	×	×	×
WESSEXIAN. Age of Polymorphidæ. See p. 266.	10. *valdani*	?	…	×	…	×
	9. *ibex*	…	×	×	…	×
	8. *ellipticum*	..	…	×		
	7. *bronni*		…	×	?	
	6. *Platypleuroceras*	×	×	×	?	×
	5. *trivialis*	…	×	×	…	×
	4. *jamesoni*	×	×	…	…	×
	3. *pettos*	…	…	×	…	×
	2. *peregrinum*	…	…	×		
	1. *Phricodoceras*	…	×	×	…	×
RAASAYAN. Age of Deroceratidæ and Echioceratidæ. See p. 267.	7. *leckenbyi*	×	×	×	×	×
	6. *aplanatum*	×	×	…	×	
	5. *macdonnellii*	×	×	…	×	
	4. *raricostatoides*	×	…	×	ptly.	×
	3. *bispinigerum*	×	?	×		
	2. *subplanicosta (densinodum)*	×	×	×	?	×
	1. 1st *Echioceras*	×	×	…	?	

TABLE IX (*continued*).

Faunal Horizons.		West Scotland.	Yorkshire.	Dorset Coast.	Rhone Basin.	Würtemberg.
DEIRAN.	8. *(lymense)*	...	...	×		
Age of	7. *Radstockiceras*	...	...	...	×	
Oxycone	6. *Gleviceras*	...	...	×	×	?
Arietids.	5. *polyophyllum*	...	×			
See p. 269.	4. *oxynotum*	...	...	...	...	×
	3. *biferum*	...	...	...	...	×
	2. *simpsoni*	...	×			
	1. *Gagaticeras*	...	×	...	×	
MERCIAN.	7. *denotatus*	...	×	...	×	×
Age of	6. *stellare*	...	...	×	×	
Catagenetic	5. *planicosta*	...	×	×	...	×
Arietids.	4. *sagittarium*	...	×	...	...	×
See p. 271.	3. *obtusum*	...	×	×		
	2. *brooki*	×	...	×		
	1. *turneri*	×	..	×		
LYMIAN.	8. *birchi*	×	...	×	×	×
Age of	7. *Arnioceras*	×	×	×	×	×
Anagenetic	6. *Agassiceras*	×	×	?	×	×
Arietids.	5. *gmuendense*	×	...	...	×	×
See p. 273.	4. *vercingetorix*	...	?	?	×	×
	3. *bucklandi*	...	...	...	...	?
	2. *rotator*	...	...	×	?	×
	1. *Vermiceras*	×	×	×	?	×

[For the Hettangian sequence, see Appendix by Mr. Tutcher, p. 278.]

1 Suggested on the evidence of a fauna in the Yeovil & Bridport Sands.

2 See S. S. Buckman & E. Wilson, Q. J. G. S. vol. lii (1896) p. 688, footnote 2.

3 In Würtemberg Quenstedt's Lias ϵ (=middle and lower parts of Whitbian) seems to be fragmentary; but, on the other hand, it would appear to possess certain horizons of its own not yet separated out in other areas.

4 *Frechiella subcarinata* is a notable and easily recognized species; but, perhaps, somewhat too rare to be quite suitable for this scheme. It is in use for the horizon where *Hildoceras-bifrons* forms are abundant. To prevent misconception it is advisable to analyse further. *F. subcarinata* without *H. bifrons* forms is not yet known to me; but the latter are found where the former is lacking. *F. subcarinata* occurs in Yorkshire, the Midlands, in Somerset, but not in Dorset nor Gloucestershire. It occurs in the Rhone Basin, the Austrian Alps, and Italy, but not in Würtemberg. Its rarity may account for its absence, say, from Gloucestershire, but can hardly be pleaded for the well-searched Dorset Coast, and certainly not for so well-worked an area as Würtemberg. Absence of a special deposit seems to be the explanation required there.

5 The fauna of horizons 1–3 are illustrated in Reynès, 'Géol. Pal. Aveyron.' 1868 Monestier's paper, *jam cit.*, refers to the same district.

best results the label should give not only the name of the place, but the exact exposure—the more detailed the better. Then the sequence of dissimilar faunas can be ascertained, especially when the exposures stretch across the line of strike.

But, even with localities alone, much can be done by analysis and comparison.

Another lesson may be learnt—it has been taught that the absence of the zone-species did not invalidate the placing of the strata in such a zone, provided that the stratigraphical position was accordant: it was only a local peculiarity. Such an assumption is now seen to be very unsafe: such cases must be looked upon with considerable suspicion. Dissimilar faunas, of locomotive organisms like Ammonites, in contiguous areas are products, not of zoological, but of stratigraphical differences. There are zoological provinces; but the absence of a southern fauna from a northern area may mean less for difference of date than the absence of a northern fauna from a southern area. Yet in the case of two areas in approximately the same latitude, the absence from one of a fauna well-developed at the other, both said to be on the same horizon, may well cause doubt as to their contemporaneity. This is a true case of dissimilar faunas.

The need for a much more systematic and continuous palæontological output and for fuller illustration of species is obvious from this investigation, where much difficulty of interpretation is due to the uncertainty of unillustrated records. Such an investigation as this is both hindered and hampered by the present condition of palæontology, which cannot keep pace with,—in fact, is continually falling behind, the discovery of new material. Such palæontological study requires very considerable time; and the facilities for its prosecution and publication seem to be inadequate.

Finally, I take the whole responsibility for the interpretations that I have placed on the information and evidence laid before me; it must not be thought that my informants necessarily concur in my views. For any mistakes—and it is too much to expect freedom from error—I shall be to blame; but I will be grateful for any facts which expose them.

Appendix I. The Zonal Sequence in the Lower Lias (Lower Part). By J. W. Tutcher.

(1) Introduction.

The district of North Somerset and South Gloucestershire—approximately that occupied by the Bristol Coalfields—has chiefly come under my observation. In this district the Lias has been thrown into a series of folds having, in the main, an east-to-west trend. These folds increase in intensity from north to south, becoming more marked as the Mendip Hills are approached. Partial and repeated denudation of the Jurassic rocks has followed

folding, thus causing numerous local non-sequences. In the neighbourhood of Radstock the *sauzeanum* zone, in which occurs the large number of *Spiriferina walcotti* for which that place is noted, may be found resting indifferently on any earlier zone down to *langportensis* (White Lias, see Table X below).

In the Keynsham area, which lies in the middle of the district under consideration, the Lias occupies a shallow syncline, and the beds have not been denuded to the same extent as those on the south and north. Chiefly in this area the faunal sequence of the Sinemurian deposits has been determined.

The Hettangian deposits, as a whole, are best displayed in an area of which Bristol is the centre.

In the following table it will be observed that the White Lias is included with the Hettangian. In common with the late Dr. A. Vaughan and the late Edward Wilson, I have always held the view that, for palæontological reasons, the line dividing Lias from Rhætic (Hettangian from Rhætian) should be drawn at the base of the White Lias. Mr. Buckman, it may be remarked, has expressed the view that the Hettangian should be regarded as the final phase of the Trias—on the grounds of the biological characters of Ammonites, the decadent characters of *Psiloceras* and allies, and the new departure (anagenetic characters) of the Arietidæ of the Sinemurian.[1]

TABLE X.—ZONES OF THE LOWER LIAS (LOWER PART).

Ages.	Zonal terms.	Name of Index fossil.
SINEMURIAN.	*turneri.*	*Arietites turneri* (J. de C. Sowerby).
	sauzeanum.	*Agassiceras sauzeanum* (D'Orbigny).
	scipionianum.	*Ætomoceras scipionianum* (D'Orbigny).
	gmuendense.	*Coroniceras gmuendense* (Oppel).
	bucklandi.	*Coroniceras bucklandi* (J. Sowerby).
	rotiforme.	*Coroniceras rotiforme* (J. Sowerby).
	conybeari.	*Vermiceras conybeari* (J. Sowerby).
HETTANGIAN.	*angulata.*	*Schlotheimia angulata* (Schlotheim).
	liasicus.	*Alsatites liasicus* (D'Orbigny).
	[*megastoma.*	*Wæhneroceras megastoma* (Wæhner)].[1]
	johnstoni.	*Caloceras johnstoni* (J. de C. Sowerby).
	planorbis.	*Psiloceras planorbis* (J. de C. Sowerby).
	Ostrea.	*Ostrea liassica* Strickland, and its mutations.
	tatei.	*Pleuromya tatei* Richardson & Tutcher.[2]
	langportensis (White Lias).	*Volsella langportensis*, Richardson & Tutcher.[3]

[1] Not found in the district, but a *Wæhneroceras* fauna occupies this position elsewhere. See p. 280.
[2] Proc. Yorkshire Geol. Soc. vol. xix (1916) p. 52 & pl. viii, fig. 3.
[3] *Ibid.* p. 54 & pl. ix, fig. 11.

[1] 'Jurassic Time' Q. J. G. S. vol. liv (1898) pp. 444–47.

(2) Remarks on the Zones.

The *turneri=semicostatum* Zone (*pars*) auctt.—More than one species of *Arietites* passes under this trivial name; it is, therefore, desirable to indicate the form intended. This is an evolute shell, with compressed sides, and rectangular whorl-section, agreeing with the upper figure in pl. ccccli of the 'Mineral Conchology,' but not with Wright's figs. 1–3 in pl. xii of his 'Monograph of the British Lias Ammonites.'

Numerous specimens of *Arnioceras* are associated with *A. turneri* in this district, but since *Arnioceras* spp. also occur abundantly in the *sauzeanum-gmuendense* zones, while *A. turneri* is not found at these levels, the last-mentioned makes the better zonal fossil.

The *sauzeanum* to *conybeari* Zones.—These zones are well exhibited in the quarries about Keynsham. The beds are of no great thickness, but they are very fossiliferous, and the faunal succession is quite clear. North and south of Keynsham some of these zones are missing, notably *conybeari* and *rotiforme*, while paucity of deposit and penecontemporaneous erosion have resulted in considerable compression of those remaining.

The *angulata*, *liasicus*, and *megastoma* Zones.—The beds containing numerous species of *Schlotheimia* are well developed over much of this district, although rarely complete at any one place. Careful study of these beds has suggested division into two well-marked zones which have more than local application. The *angulata* zone is thus restricted to the beds in the upper part of the series. These beds contain, in addition to the index-ammonite and numerous allied species, an abundance of *Rhynchonella calcicosta* Davidson (*non* Quenstedt). In the lower division (*liasicus* zone) *Alsatites liasicus* (D'Orbigny), *Schlotheimia gallica* S. Buckman, and *Ornithella sarthacensis* (D'Orbigny) are common fossils, and they do not pass into the upper division.

No species of *Wæhneroceras* have been obtained in this district, and a non-sequence between *johnstoni* and *liasicus* deposits is therefore assumed. Ammonites of this genus have, however, been recorded from Hock Cliff, near Fretherne (Gloucestershire),[1] and from Evesham (Worcestershire).[2]

An important *Wæhneroceras* fauna occurs at Kayes Cementworks, Long Itchington, near Southam (Warwickshire). The extensive quarry at this place shows the following sequence:—

conybeari.	*Vermiceras* spp., *Coroniceras* spp.
angulata.	*Schlotheimia angulata*, *Schl. striata* (Quenstedt). *Rhynchonella calcicosta* Davidson.
liasicus.	*Alsatites liasicus* (D'Orbigny), *Schlotheimia* spp. *Ornithella sarthacensis* (D'Orbigny).
megastoma.	*Wæhneroceras extracostatum* (Wæhner), with many other examples of the genus.

[1] L. Richardson, Proc. Cotteswold Nat. F. C. vol. xvi (1908) p. 141.
[2] S. S. Buckman, *ibid.* vol. xv (1906) p. 246 & pl. x, figs. 5–6.

The specimens of *Wæhneroceras* were obtained by Dr. Robson, of Birmingham. He was informed by the quarrymen that these specimens came from a temporary excavation at the base of the section. On the occasion of my visit this excavation was water-logged, and could not be examined. There is, however, every reason to believe that the statement of the quarrymen is correct. The state of preservation of the specimens is distinctive; they are cleanly-cut casts in a bluish-grey matrix with some pyrites, and no fossils have been found in a similar condition and matrix in any part of the quarry usually worked.

The *johnstoni* Zone.—The ammonite of most frequent occurrence in this zone in the Bristol district is *Caloceras intermedium* (Portlock), but fragments attributed to *C. johnstoni* have been obtained.

The *planorbis* Zone.—The true *Psiloceras planorbis* is rare in the Bristol district; a more evolute form, *Ps. sampsoni* (Portlock), and a costate form, *Ps. plicatum* (Quenstedt), are the dominant species.

The *Ostrea*, *tatei*, and *langportensis* Zones.—The term *Ostrea* Zone has generally been used to distinguish all the Lias deposits below those in which ammonites occur. It is now proposed to restrict this term to the beds immediately preceding the *planorbis* zone: in these beds *Ostrea liassica* and its mutations attain their maximum.

Ostreæ of the *liassica* type also occur in decreasing numbers in the lower beds; but, in these deposits, other fossils acquire greater importance.

The White Lias is characterized by *Volsella (Modiola) langportensis*, which appears to be confined to these beds.

Between the White Lias and the maximum of *Ostrea liassica* and its allies, there is a series of beds, more or less continuous from Dorset to Yorkshire, containing in abundance *Pleuromya tatei*. The application of this fossil to zonal purposes has, under an older name (*Pleuromya crowcombeia*), and in a somewhat less restricted sense, already been suggested by Dr. A. Vaughan in collaboration with the present writer,[1] and by Dr. Rendle Short.[2]

R. Tate & J. F. Blake designate the beds in which this fossil occurs in Yorkshire 'The *Pleuromya* Limestones.'[3]

[1] Proc. Bristol Nat. Soc. n. s. vol. x, 1903 (issued for 1901), pp. 52, 53 see also A. Vaughan, Q. J. G. S. vol. lix (1903) p. 400.

[2] Q. J. G. S. vol. lx (1904) pp. 187, 188.

[3] 'The Yorkshire Lias' 1876, p. 38.

Appendix II.

Mayer-Eymar's Stratigraphical Terms.

Since this communication was read Dr. A. Morley Davies has kindly brought to my notice a paper by Mayer-Eymar containing a scheme of stratigraphical terms. This paper seems to have been overlooked generally, perhaps on account of its rarity. As there is no copy in the Geological Society's Library it seems desirable to transcribe the necessary portion. I am much indebted to the courtesy of Prof. Watts for the opportunity to do so. The paper is entitled 'Die Filation der Belemnites acuti' (Vierteljahrschrift der Zürcher Naturforschenden Gesellschaft, April 1884), and the stratigraphical scheme is to explain the sequence of strata containing these belemnites. The author speaks of a previous scheme published three years earlier: substantially the same, one may presume, but I have not been able to see it. I am, however, indebted to our Librarian, Mr. C. P. Chatwin, for bringing to my notice in answer to my enquiries about this prior paper, another communication by the author in the same year (1884)—a paper of eight lithographed folios giving a classification of all strata.

The following Table XI (p. 283) is the table in the pamphlet first cited, with certain correlations.

By the side of Mayer-Eymar's table are placed the divisions adopted in the present communication, and, alongside those, Quenstedt's divisions of the Lias; but it cannot be claimed that the Swiss author's divisions are rightly interpreted. For instance, it is doubtful whether the Hwiccian is correctly correlated with his Mendin: that may be intended for the lower part of the Domerian; and perhaps it is incorrect to leave the Raasayan without equivalent: some of the basal strata of the Rottorfin and upper horizons of the Balingin may fall within its limits. But Continental authors have apparently only had the opportunity of seeing isolated fragments of strata of Raasayan date, and may perhaps have correlated these fragments criss-cross, placing earlier strata of one locality above later strata of another. We had certainly done that in this country before the Raasay deposits gave the clue.

Had I known about Mayer-Eymar's scheme I should have hesitated to propose some of the new terms; but my terms were in print before his paper came to my notice.[1] So I must leave selection in the hands of my fellow-workers.

[1] Abs. Proc. Geol. Soc. 1916–17, No. 1009, p. 84.

TABLE XI.[1]—MAYER-EYMAR'S SCHEME, WITH CORRELATION.

	Mayer-Eymar's Terms.	*Terms of present paper.*	*Quenstedt's Lias Divisions.*[2]
	Mittleres Jura-System.[1]		
'BATHIAN (Mayer-Eymar).	II. Bedfordin. — Niveau der *Terebratula lagenalis.*		
	I. Bradfordin.—Niveau des *Apiocrinus Parkinsoni.'*		
'VESULLIAN (Mayer-Eymar).	III. Falaisin.—Niveau der *Nerinea Voltzi.*		
	II. Stonesfieldin.—Niveau des *Clypeus Ploti.*		
	I. Cadomin.—Haupt-Niveau der *Ostrea acuminata.'*		
'BAJOCIAN (D'Orbigny).	III. Ehningin. — Haupt-Niveau des *Ammonites Parkinsoni.*		
	II. Scarboroughin.—Niveau des *Ammonites Humphriesi.*		
	I. Maconin.—Haupt-Niveau des *Ammonites Sowerbyi.'*		
'AALENIAN (Mayer-Eymar).	III. Cheltenhamin.—Niveau des *Ammonites Murchisonæ.*		
	II. Gundershofin.—Niveau der *Trigonia navis.*		
	I. Bollin.—Niveau des *Ammonites torulosus.'*		
'TOARCIAN (D'Orbigny).	III. Alfeldin.—Haupt-Niveau des *Ammonites Jurensis.*	Yeovilian.	ζ
	II. Altorfin.—Niveau des *Belemnites acuarius.*	Whitbian.	ε
	I. Pliensbachin.—Niveau des *Belemnites papillatus.'*		
	Unteres Jura-System.		
'CHARMOUTHIAN (Mayer-Eymar).	III, *a*, *b*. Banzin. — Niveau des *Pecten æquivalvis.*	Domerian.	δ
	II *a*, *b*. Mendin.—Haupt-Niveau des *Ammonites fimbriatus.*	Hwiccian.	
	I, *a*, *b*. Rottorfin.—Niveau des *Ammonites Jamesoni.'*	Wessexian.	γ
		Raasayan.	
'SINEMURIAN (D'Orbigny).	II, *a*, *b*, *c*. Balingin.—Niveau des *Ammonites oxynotus.*	Deiran.	β
	I, *a*, *b*. Filderin.—Haupt-Niveau der *Gryphæa arcuata.'*	Mercian.	
		Lymian.	α
'RHÆTIAN ([Gümbel] M.-E.)	II, *a*, *b*. Hettangin.—Niveau des *Ammonites angulatus.*	Hettangian.	
	I. Kœssenin.—Niveau der *Avicula contorta.'*		

[1] The lithographed paper differs in not giving definite divisional terms such as 'Banzin' and so on, but speaks only of 'Couches de Banz' and so on.

[2] Quenstedt's Lias ζ includes beds higher and lower than Yeovilian, and his Lias ε is of less extent than Whitbian.

Appendix III. Palæontology.

(*a*) Introduction.

In the following pages are given descriptions of certain Lias species which are of importance, either because they are additions to the British fauna, and therefore their recognition may be useful in future work, or because they are of stratigraphical significance. Some few of them happen also to be interesting morphologically and biologically; but only casual notice of such features is appropriate now.

A few words of explanation may be given here in reference to the descriptions. The proportions are stated always in the order proposed in 'Yorkshire Type Ammonites' ii, p. viii (1913).—Diameter in mm., breadth of whorl, thickness, size of umbilicus in percentage of diameter; S., measurements from actual specimens, F., from figures,[1] T., from text-statements of author. Other details about descriptive terms will be found in the same place.

At the close of the descriptions I append a few remarks as to the bearing of the described species on the geological-chronological problem (p. 307).

(*b*) Descriptions of Species.

Family HILDOCERATIDÆ.

Genus Leptaleoceras,[2] nov.

Type, *L. leptum*, sp. nov.

Definition.—An umbilicate, plate-like, obscurely costate, gammiradiate, stoutly carinate, non-sulcate Hildoceratid. Carina apparently degenerately septicarinate, that is, the cast may not be carinate or so carinate, thus indicating a one-time septate condition; but there is apparently no distinct hollow in the keel: details, however, are obscure. The radial line is of the gamma pattern of *Grammoceras*, very slightly flexed laterally, produced ventrally, but not excessively.

Distinction.—The stout carina recalls *Tiltoniceras* S. Buckman,[3] but shape, ornament, and radial line are wholly different. There is some suggestion of *Grammoceras* Hyatt, but this plate-like thin form could not give rise to the stout costates of that lineage. There is a nearer approach to *Protogrammoceras* Spath,[4]

[1] Measurements (especially of small forms) are difficult to obtain accurately. In the case of figures it seems best to lay tracing-paper, and then by a ruler mark diameter and proportions with a sharp pencil. This ensures a true diameter being followed, and saves the plate from the compass-points: the only error may be from the shadow of the umbilical wall.

[2] Λεπταλέος thin, fine, delicate.

[3] 'Yorkshire Type Ammonites' ii (1913) p. *viii*.

[4] Q. J. G. S. vol. lxix (1913) p. 547.

particularly in the plate-like shape; and the penultimate whorl-section of Spath's type agrees with the ultimate whorl-section of this genus, suggestive perhaps of common ancestry; but the present genus shows no peripheral sulcation, and has a decidedly different radial line.

Remarks.—Spath says that his genus is 'probably .... far too comprehensive.'[1] It is, therefore, inadvisable to enlarge it for the reception of this form.

LEPTALEOCERAS LEPTUM, sp. nov. (Pl. XXVI, figs. 1 *a*–3 *b*.)

Description.—Serpenticone; substeno-leptogyral; subextremilatumbilicate; periphery subtabulate, joining a stout fastigate carina with only a slight angle; gammiradiate; lateral area smooth to costulate to smooth.

General details.—The flat, little-overlapping whorls give to the species a disc-like appearance. The inner whorls are somewhat elliptical in section, the outer whorl is suboblong, thickest about the middle, sloping slightly to the periphery, more to the umbilical edge, which is tabulate, narrow and defined in the last whorl, but indistinct previously. The inner whorls are smooth until about 14 mm. diameter; then furnished with subobscure, undulate costulæ which die away nearly to smoothness at about 53 mm. diameter—there remain only occasional traces of the previous costulæ with fine growth-lines, and ultimately only the latter.

Remarks.—Three specimens are before me, all very similar; but the medium-sized one seems to differ in thickness and slightly in other proportions from the holotype at the same diameter.

The likeness of the smooth anagenetic stage to the similar stage in *Arnioceras* is noticeable (see p. 268).

Distinction.—The considerable Italian literature on Domerian Hildoceratidæ has revealed neither to Mr. Lang nor to myself anything really like this species. I am much indebted to Mr. Lang for kind assistance in bibliographic matters in connexion with this Appendix—an important aid at the present time when facilities are so much curtailed.

Below I give proportions of the examples of this species and of others which have some approximation. Of these *Ammonites fieldingi* seems to be the only one possibly of this genus; but its radial line is perhaps too curved: it would represent the smooth or almost smooth anagenetic stage in this or a parallel line; *A. pseudoradians* has the right style of radial line, but a different style of ribbing, and shows no sign of the smooth anagenetic stage; *A. normanianus* has the style of ribbing, but much too curved a radial line; and the others differ by being carinatisulcates, with also a too-much flexed radial line.

[1] Q. J. G. S. vol. lxix (1913) p. 580.

History of figured specimens.—The holotype is from the collection of Mr. D. S. Darell, F.L.S., F.G.S., and was obtained from South Petherton (Somerset), evidently by its matrix from Marlstone or associated beds. The other two specimens were purchased by Mr. J. G. Hamling, F.G.S., at the sale of the effects of the late Rev. Ingle Dredge: they were in a drawer labelled 'Middle Lias, Gretton.' The piece of matrix which yielded the larger specimen was preserved too—a very good practice: it is a bluish calcareous stone of Marlstone character, and Gretton near Winchcomb (Gloucestershire) was a well-known Marlstone locality. See later, p. 308. I desire to express my thanks to Mr. Hamling for kind presentation of these specimens.

Table XII.—Proportions: *Leptaleoceras* and like Forms.

L. leptum, young shell	S. 25,	34,	19,	40.
L. leptum, holotype [1]	S. { 24,	33,	18,	41.
	35·5,	30,	17,	43.
	66,	24,	16,	52.
L. aff. *leptum*	S. 35·5,	34,	20,	39.
Ammonites normanianus D'Orbigny [2]	T. 90,	31,	17,	45.
Protogrammoceras cornacaldense, var. *zeugitanum* Spath, lii, 1 *a* [3]	T. 60,	30,	18,	46.
Am. pseudoradians Reynès, i [*bis*], 4 [4]	F. 46,	37,	21,	37.
Am. fieldingi Reynès, iv, 1 *a*, *b* [4]	F. 24,	33,	24,	47.
Harpoceras domeriense Meneghini, App. i, 5 [5]	F. 31·5	30,	26,	48.

Family POLYMORPHIDÆ.

Acanthopleuroceras rursicosta, nom. nov. (Pl. XXVI, figs. 4 *a*–4 *c*.)

1884. *Ammonites valdani* Quenstedt (*non* D'Orbigny), 'Ammoniten d. Schwäbischen Jura' pl. xxxv, fig. 4 only.

Proportions.—S. { 260, 28, 20, 48.
190, 32, 22, —.

Description.—The features of the type are its large size and the reclination of the ribbing. The general features are well shown in Quenstedt's cited figure—the reclination is less; but increase of reclination may be due to age, to which also is to be attributed loss of inner row of tubercles, rounding of periphery, and decay of keel. The proportions of Quenstedt's fragment I estimate at F. 112, 30, 20, 48.

Distinction.—Reclination of ribs, presence of many marked subsidiary costulæ on periphery, less size of tubercles, convexity instead of concavity of intertuberculate lateral area distinguish

[1] The specimen being broken, approximate measures of inner whorls can be given.
[2] 'Pal. franç.: Terr. Jur. Céph.' 1844, pl. lxxxviii & p. 291.
[3] *Op. jam cit.*
[4] 'Géol. Pal. Aveyron.' 1868.
[5] 'Lias sup.' in Stoppani's Pal. Lomb. (4) 1881.

this species from *Ammonites valdani* D'Orbigny.[1] Its whorls are also somewhat broader and thicker. The proportions that he gives are T. 95, 27, 17–19, 48.

History of figured specimen.—Given to me many years ago by the late Rev. F. Smithe, F.G.S., with other large species, as having been found in the Middle Lias clays of Leckhampton (Gloucestershire), when the Banbury & Cheltenham Railway was constructed.

Family ARIETIDÆ.

Genus RADSTOCKICERAS,[2] nov.

Type, *R. complicatum*, nov.

Definition.—Oxycone, highly involute, septicarinate; periphery concavifastigate. Radial line indistinct, laterally slightly flexed? slight curving forwards on outer third. Suture-line very highly complicated—one line touching the preceding at so many points as to make the separation of the chambers a very difficult process. The peripheral lobe has two long branches, and five well-developed branches penetrate the external saddle, four of them off the side of the peripheral lobe; the superior lateral lobe narrow-stemmed, strongly trilobate, unequal; inferior lateral lobe broad-stemmed, with short lobules; a considerable array of auxiliary lobes.

Distinction.—The high degree of specialization of suture-line distinguishes this genus from *Oxynoticeras*. Involution is rather more developed; periphery is on rather a lower grade, but is beginning to show the knife-edge of that genus, while suture-line is well beyond it: the array of lobes external to the superior lateral lobe is greater in number and more developed, that lobe is specialized into a long narrow-stemmed lobe of cruciform pattern; while it is the inferior lateral lobe which is in the same stage as the superior lateral of *Oxynoticeras*—broadly U-shaped with short lobules.

RADSTOCKICERAS COMPLICATUM, sp. nov. (Pl. XXVII, figs. 1 *a* & 1 *b*; text-figs. 6, p. 294 & 12, 21, p. 295.)

Description.—Oxycone: subextremiplaty-leptogyral; angustumbilicate; periphery concavifastigate, septicarinate; subdistanti-obscuricostate, gammiradiate; complicati-septate.

General details.—The type is wholly septate: there are indications of its having lost more than another half-whorl, so that it was a giant of about 380 mm. or nearly 16 inches in diameter. The periphery is not true knife-edge—the side falls into the keel with a concave depression; ribs are rather distant and obscure; greatest breadth is about one-third from the umbilical border which

[1] 'Pal. franç.: Terr. Jur. Céph.' 1844, pl. lxxi & p. 255
[2] Radstock (Somerset).

falls somewhat steeply to the umbilicus; excentrumbilication is apparent in the last half-whorl (beyond the part preserved)—the overlap decreasing from about four-fifths to two-thirds.

Remarks.—In ornament, periphery, and general appearance the species here described conforms with *Ammonites buvigneri* Dumortier; but it differs in having a larger umbilicus with a much steeper border and a thinner whorl the greatest thickness of which is not on the edge of the umbilical border but well removed from it.

Ammonites buvigneri D'Orbigny is a much thinner species than Dumortier's, and has passed beyond the costate stage. Its umbilicus is much smaller than the Radstock species; its suture-line shows the general pattern thereof, but is not truly conformable in many respects: it does not seem so highly developed: the lobules which penetrate the external saddle are much less developed and different—the first lobule is long and bipartite in the Radstock species, short and simple in D'Orbigny's; the superior lateral lobe has its outer lobule bipartite in the Radstock example, its inner one is so in D'Orbigny's: in the former the terminal lobule has its shortest side internal (endobrachysceles), in the latter external (ectobrachysceles).[1] The specimens figured by Dumortier and D'Orbigny are both separable from the Radstock species by greater occlusion—they are perangustumbilicate. Pompeckj says that these two ought to be considered as the same species:[2] I differ.

Phylloceras buvigneri Wright is also a perangustumbilicate oxycone, comparable as regards sculpture with D'Orbigny's species, but wholly different in whorl-shape and in suture-line. It looks as if all these oxynotes are homœomorphous terminals of different lineages—their polygenetic origin shown by the different character which each selects for acceleration—in one case suture-line, in another, ornament, in another, inclusion, in another, whorl-shape. Considerable inequality of characters is thus produced.

For references and proportions see Table XIII, below.

History of figured specimen.—From Radstock Grove (Kilmersdon Colliery), Radstock, Somerset, [from beds yielding Oxynotoids immediately below the so-called '*raricostatus* beds']. Purchased. See p. 310.

Table XIII.—Proportions: *Radstockiceras* and like Forms.

Radstockiceras complicatum nov.	S. 136,	54,	25,	11.
	S. 262,	55,	25,	11.
Ammonites buvigneri D'Orbigny[3].	F. 200 (93),	56,	21,	4.
	T. 200,	58,	21,	4.
Ammonites buvigneri Dumortier[4].	T. 126,	58,	28,	4.
Phylloceras buvigneri (Wright), lxxvi, 1, 2[5]	F. 150,	54,	30,	7.
	T. 145,	56,	32,	4.

[1] 'Monogr. Inf. Oolite Ammonites' p. 381.
[2] 'Oxynot. Siném.' Comm. Serv. Geol. Port. vi (1906) p. 270.
[3] 'Pal. franç.: Terr. Jur. Céph.' 1844, pl. lxxiv & p. 261.
[4] 'Bassin Rhône' ii (1867) pl. xxxiv, p. 147.
[5] 'Monogr. Lias Ammonites' (Pal. Soc.).

Genus Gleviceras,[1] nov.

Type, *G. glevense*, nov. (paratype).

Definition.—Involute, septicarinate suboxycone, passing to less involute, non-septicarinate platycone—the periphery broadening, carina declining (passing to rounded, uncarinate?), whorls inflating. Ribs subregular, simple. Radial line laterally nearly straight with distinct forward projection, less in stage of rib-decline. Suture-line somewhat complex—no long branches from the external lobe, one accessory lobule in the external saddle, superior lateral lobe rather long, narrow-stemmed, but declining to broad-stemmed later.

Distinction.—From *Oxynoticeras*, the suture-line is more developed, but the oxyconic character is much less developed,—return towards platycone commencing before anything like the knife-edge periphery of *Oxynoticeras* is attained. From *Radstockiceras*, with a lower stage of involution and a rather less developed periphery this genus combines a less complicated suture-line. From *Agassizoceras*, of which at one time I thought it might be an involute development, a suture-line too much developed. See also another character below, p. 292.

Remarks. The various species which appear to belong to this genus are those cited in the Comparative Table. *Ammonites guibalianus* D'Orbigny and *A. victoris* Dumortier must be excluded for various reasons. See below, p. 293.

Gleviceras glevense, nom. nov. (Pl. XXVII, figs. 2 & 3; Pl. XXVIII, figs. 1 & 2; Pl. XXIX, fig. 3; Pl. XXX, fig. 4; text-figs. 4 & 5, p. 294; 11, 20, p. 295.)

1844. *Ammonites greenhoughii* J. Buckman, 'Geol. Chelt.' new ed. p. 89.
1881. *Amaltheus guibalianus* Wright, 'Mon. Lias Amm.' pl. xlv, figs. 6 & 7 only.
1904. *Agassizoceras greenoughi* S. Buckman (*non* Sowerby) in L. Richardson, 'Handbook of the Geology of Cheltenham' p. 212.
Cf. 1879. *Ammonites guibali* Reynès (*non guibalianus* D'Orbigny), 'Mon. Amm.' pl. xlvi, fig. 13 only.

General details.—Whorls broad (inner margin rounded), inclusion nearly to the inner edge of the preceding whorl up to 128 mm. diameter, in another ¾ whorl (not preserved) umbilical expansion rapid, inclusion only about ⅖. Periphery sloping ogival, with raised hollow keel up to about 86 mm. diameter, in another half-whorl keel small, hollow character obsolescent, periphery flattening but narrower than dorsum, in another half-whorl periphery flatly ogival, almost as broad as dorsum, carina almost obsolete. Ribs indistinct, undulate, occasionally bifurcate on the outer margin: they tend to become irregularly obsolete at or after 145 mm. diameter, when irregular swellings (old-age rugosities) appear.

[Final stage (not preserved), smooth (or irregularly swollen) with rounded uncarinate periphery and excentrumbilication?]

[1] Glevum, the Roman name for Gloucester.

Remarks.—These details are drawn up from the holotype. The paratype, *Ammonites greenhoughii* of the 'Geol. Chelt.,' agrees so closely with Wright's cited figures of *Amaltheus guibalianus* and his description of that form (p. 386), that there need be added only these remarks:—The periphery in Wright's figure is sharper, possibly due to presence of test, the ribs are stronger—over-accentuation of such a character is quite usual in drawings,—and the inner edge of the penultimate whorl is more exposed: the paratype, and the holotype too, show a particularly concentric coiling of the umbilicus, which may be called thimble-shaped, indicating that in the young the species must be rather thin and somewhat widely umbilicate.

The paratype shows (Pl. XXVIII, fig. 2) a rather narrow-stemmed superior lateral lobe, with a fairly even arrangement of fine lobules towards the end: the broader-stemmed lobe of the holotype is presumed to be due to old age.

Below are given the proportions of certain comparable species with those of the species now described. The first three differ in proportions, especially in the greater umbilication; Reynès's *Ammonites guibali* is difficult to place in the series, as no information is given of thickness nor whether it is a large shell reduced.

The very longstanding and very general confusion of Oxynotoids of the *Gleviceras* pattern with *Ammonites greenoughi* J. Sowerby has now been exposed and corrected in a very careful paper by Mr. Spath.[1] But the likeness when, in large specimens of the present species, ribs are lost and the keel is obsolescent or obsolete is certainly remarkable.

History of specimens.—The holotype is from Lias clays above the *oxynotum* horizon, from the lower part of Folly Lane Brickyard, Cheltenham (Gloucestershire). The paratype was recorded as *Ammonites greenhoughii* from Lias shales, Lansdown, Cheltenham, Coll. J. Buckman ('Geol. Chelt.' p. 89).

TABLE XIV.—PROPORTIONS: *GLEVICERAS* AND LIKE FORMS.

Am. doris Reynès, xli, 13–15[2] ...	F. 109,	48,	32,	22.
Am. aballoensis Dum. II, xxxviii.[3]	F. 117,	48,	35,	20.
Am. greenoughi Hauer, xii, 2, 3, 4.[4]	F. 112,	48,	29,	20.
Am. guibali Reynès, xlvi, 13[2] ...	F. 203,	47,	—,	20.
Gleviceras glevense, holotype	S. 86,	47,	25,	19.
	S. 128,	51,	26,	14.
	S. 184,	51,	27,	14.
G. glevense, paratype .... (*Am. greenhoughii* J. Buckman.)	S. 148,	52,	26,	14·5.
G. glevense. (*Amaltheus guibalianus* Wright, xlv, 67, p. 386)[5]	F. 157,	54,	26,	14.
	T. 133,	·56,	26,	·15.

[1] '*Schlotheimia Greenoughi*' Geol. Mag. dec. 6, vol. ii (1915) p. 97.
[2] 'Mon. Amm.' 1879. [3] 'Bassin Rhône.'
[4] 'Ceph. N.O.-Alpen' Denkschr. k. Akad. Wissensch. Wien, vol. xi, 1856.
[5] 'Monogr. Lias Ammonites' (Pal. Soc.) 1881.

[Since this paper was read various other items of *Gleviceras* belonging or akin to the present species have come to light, and are of particular interest.

A large septate specimen from the same place as the holotype, and like it only a half, has, however, stouter proportions: it is, perhaps, more phylogerontic. It shows about a quarter-whorl more: but, what is chiefly interesting is, that the mark of the inner margin indicates that another complete whorl at least must have been present.[1] As the specimen now measures 204 mm. it must, judging by the proportion of radius to diameter as well as by curvature, have been a giant of some 450 mm. diameter. But this inner margin line shows excentrumbilication; for, whereas about 80 per cent. of the whorl was enveloped at one time, in a whorl this has decreased to about 66 per cent., and in less than another half-whorl to about 50 per cent. From this specimen the following proportions may be ascertained:—

S.	140,	52,	35,	(16?).
	204,	51,	33,	19.
	450,	45,	—,	25.

The umbilicus in old age returns to the somewhat open condition of youth, which is possessed by the young form described in the following paragraph.

The next specimen, quite a young example, is also from the same place: envelopment is about half the whorl; ribs are regular, with occasional bifurcation: there are no signs of auriculoids on the exposed part of the whorl, but there is evidence that they existed in the young stage: the line of the inner margin does not follow a regular curve, but is angular (hexagonal in a turn), displaced at intervals, thrown out of its course, by the presence of the auriculoid excrescences something similar may be noted in the umbilical margin of spinous species.

This example, which is depicted in Pl. XXVII, fig. 3; Pl. XXIX, fig. 3; and Pl. XXX, fig. 4, gives the following proportions:—

S.	29,	49,	29,	24,	—K.[2]
	31,	48,	27,	22,	+K.[2]

The next specimen is from Charmouth, a 'pyritised *Oxyno-*

[1] In the course of these investigations I have made a discovery which may be of importance for the identification of types. In my father's descriptions of ammonites, 'Geology of Cheltenham' new ed. 1844 (1845), the diameter given is not that of the specimen as preserved, but is the assumed diameter of the perfect shell. Thus, in his description of *Ammonites gracilis* (p. 104), the diameter is given as 'about 9 in.' The specimen actually measures 145 mm. (5¾ inches) in diameter, but is fully septate and carries indications of another half-whorl at least, shown by remains of inner edge. The diameter of 9 inches is obviously reckoned to include this extra half-whorl or so, but is, perhaps, rather an overestimate. This method of giving diameters, now that it is discovered, clears up many discrepancies in these descriptions. It may be that other authors have adopted this plan, which might easily raise doubts as to the identity of types. There is no possible question about the identity of *A. gracilis*.

[2] Without keel, with keel.

ticeras,' presumably from Bed 92,[1] and is in the cabinet of Mr. James Francis, F.G.S., who has kindly consented to its use in illustration. It was communicated to me by Dr. A. Morley Davies, who had noticed its interest in regard to auriculoids.

This is not the same species as the last, but it is near, and it illustrates that which there is reason to suppose is the hidden stage of that one. It is earlier—that is pre-*glevense*—biologically, and may, for the present, be inscribed as *Gleviceras auritulum/glevense*. It is earlier because, though exposing three-quarters of the whorl shown by the young *G. glevense*, it retains auriculoids all the time, which feature the other had lost about a whorl before. Its ribs are also of a different pattern, somewhat irregular, connate on the inner area, joined in button-and-loop style on the outer area by the reflected **U**-shaped auriculoid: a plain rib parts each connected pair. The umbilicus is angulate. Proportions are not much different; but the periphery is rather blunter. The specimen depicted in Pl. XXX, figs. 5*a*–5*b* & Pl. XXXI, figs. 1*a*–1*b*. gives:

S. 22, 44, 29, 26, –K.

The last of these specimens is much separated by its shape, but becomes of interest now as possessing auriculoids combined with a stout whorl and flattened broad periphery.[2] It is *Ammonites riparius* Oppel,[3] from a well at Aston Cross, near Tewkesbury, presumably from the *biferum* horizon. It is thus additionally interesting, as another link between the Gloucestershire and Würtemberg faunas.[4]

Neither Oppel's figure nor description lead one to expect auriculoids; but this example shows them well developed: they are connected too by a longitudinal ridge or pseudo-carina—this is shown by Oppel. The inner margin in the umbilicus is angulate, as noticed for the two preceding specimens: not shown by Oppel.

This species may presumably be inscribed as *Gleviceras riparium* (Oppel), for it shows a suture-line (Oppel)—not well exposed in my example (but see Pl. XXX, fig. 3*d*),—which appears to be somewhat more developed than one would expect for this stage of *Oxynoticeras*; but there are obviously several steps yet to be distinctively named connecting this species with the last specimen (*G. auritulum/glevense*): they are supplied to a certain extent by Quenstedt's figures, pl. xxiv, figs. 15 & 16 in 'Ammoniten d. Schwäbischen Jura.' At any rate something very near to this species may be looked for as common ancestor of *Oxynoticeras* and *Gleviceras*, which are thus presumably traceable to a form of *Agassiceras* pattern but possessing auriculoids, and thus differing from that genus.

For further remarks on auriculoids, *Ammonites auritulus*, etc., see 'Yorkshire Type Ammonites' *A. dennyi* 1909, No. 7.]

[1] See Chronological paper, Table V facing p. 267.
[2] Its approximate proportions are: S. 32, 48, 50, 29 +.
[3] Pal. Mitth. 1862, pl. xl, fig. 2.
[4] See Chronological paper, p. 270.

Genus GUIBALICERAS, nov. (Figs. 14 & 18, p. 295.)
Type, *Am. guibalianus* D'Orbigny.[1]

Distinct from *Gleviceras* by the intermittent character of its ribbing and also by its suture-line. *Am. aballoensis* Dumortier *pars*,[2] and *Amaltheus guibalianus* Wright *pars*[3] (*non* D'Orbigny), have the intermittent style of ribbing, and presumably belong to this genus.

Genus VICTORICERAS, nov. (Figs. 13 & 19, p. 295.)
Type, *Ammonites victoris* Dumortier.[4]

Distinct from *Gleviceras* by different suture-line, peculiar character of test—striate and punctate,[5]—dichotomous style of ribbing and other characters. The dichotomy begins at the umbilicus, where there is a sort of bunching on the umbilical wall, and is repeated at several stages across the whorl, with short costulæ, dichotomous or intercalated, on the periphery.

Fine examples of *Ammonites victoris* occur with *Radstockiceras* at Radstock, with many other remarkable Oxynotoids which must be left for another opportunity.

The suture-lines of some of these Oxynotoid genera are presented in figs. 1–6, p. 294:—

Fig. 1. *Oxynoticeras oxynotum* (Quenstedt), after his figure, Ceph. v, 11.
Figs. 2 *a* & 2 *b*. *O. oxynotum* (Quenstedt), from a paratype of *Am. cultellus* J. Buckman in my collection, to show increase of complexity due to age. The specimen, wholly septate, measures 123 mm. (nearly 5 inches) in diameter; and suture-line 2 *a* is taken at a diameter of about 31 mm., 2 *b* at about 90 mm.
Fig. 3. *Oxynoticeras polyophyllum* (Simpson), after the figure in 'Yorkshire Type Ammonites' 1909, No. 8.
Fig. 4. *Gleviceras glevense*, genotype, from the specimen figured in Pl. XXVIII, fig. 2.
Fig. 5. *Gleviceras glevense*, holotype, from the large specimen illustrated in Pl. XXVIII, fig. 1.
Fig. 6. *Radstockiceras complicatum*, from the specimen depicted in Pl. XXVII, fig. 1, the suture-line × 0·67: from a photograph.

To facilitate comparison of the various Oxynotoid genera, outlines of the external lobe and saddle and the superior lateral lobe are given in figs. 8–14, p. 295:—

Fig. 8. *Oxynoticeras oxynotum*, after Quenstedt, × 2·5.
Fig. 9. *O. oxynotum* (*Ammonites cultellus*), see above, fig. 2 *b*.
Fig. 10. *O. polyophyllum*, see above, fig. 3.
Fig. 11. *Gleviceras glevense*, see above, fig. 4.
Fig. 12. *Radstockiceras complicatum*, see above, fig. 5.
Fig. 13. *Victoriceras victoris* (Dumortier), after his fig. *op. cit.* pl. xxxi, fig. 1.
Fig. 14. *Guibaliceras guibalianum* (D'Orbigny), after his fig. *loc. cit.*

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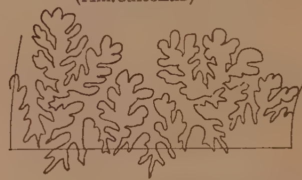
[1] 'Pal. franç.: Terr. Jur. Céph.' pl. lxxiii.
[2] 'Bassin Rhône' ii, pl. xxvii only.
[3] 'Monogr. Lias Ammonites' 1881, pl. xlv, figs. 3, 4 only.
[4] *Op. cit.* ii, pl. xlv, figs. 1 & 2.
[5] See Dumortier, pl. xxxi, figs. 1 & 2.

Figs. 1–7.—*Suture-lines of Oxynotoids and a* Deroceras.

1. Ox. oxynotum

2a Ox.oxynotum (Am.cultellus)

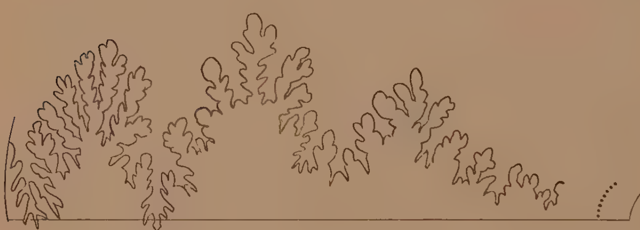
2b Ox.oxynotum (Am.cultellus)



7. Deroceras bispinigerum × 3.5

3. Ox.polyophyllum

4. Gleviceras glevense (genotype).



6. Radstockiceras complicatum × 0.67.

5. Gleviceras glevense (Holotype)

[For fig. 7, see p. 302.]

Figs. 8–21. *Suture-lines (skeleton) and radial lines of Oxynotoids.*

[In figs. 9 & 16, *for* Am. (cultellus) *read* (Am. cultellus).]

For the same purpose of comparison, outline rib-schemes are given in figs. 15–21, p. 295 :—

Fig. 15. *Oxynoticeras oxynotum*, after Quenstedt.
Fig. 16. *O. oxynotum* (*Ammonites cultellus*), see note to fig. 2 above.
Fig. 17. *O. polyophyllum*, after fig. in Y. T. A., see note to fig. 3 above.
Fig. 18. *Guibaliceras guibalianum*, after D'Orbigny.
Fig. 19. *Victoriceras victoris*, after Dumortier.
Fig. 20. *Gleviceras glevense*, from the specimen figured in Pl. XXVIII, fig. 2.
Fig. 21. *Radstockiceras complicatum*, from the specimen depicted in Pl. XXVII, fig. 1 : this outline is of the natural size.

The genotypes of these Oxynotoid genera are all in about the same stage of morphic equivalence, but all differ in degree of development of various characters. Thus, in regard to suture-line, some make more elaboration in the lobules of the external saddle, some in the superior lateral lobe; in regard to periphery, *Oxynoticeras* is the only one that has attained to the knife-edge stage, *Radstockiceras* approaches, *Gleviceras* is far from it. An analysis of the genera on these and other features gives the following results in descending order :—

Saddle.	**Sup. lat. lobe.**	**Periphery.**
5. *Radstockiceras.*	5. *Radstockiceras.*	5. *Oxynoticeras.*
4. *Oxynoticeras.*	4. *Gleviceras.*	4. *Radstockiceras.*
3. *Guibaliceras.*	3. *Victoriceras.*	3. *Guibaliceras.*
2. *Victoriceras.*	2. *Guibaliceras.*	2. *Victoriceras.*
1. *Gleviceras.*	1. *Oxynoticeras.*	1. *Gleviceras.*

Ribbing.	**Umbilicus.**	**Result : Nat. Order.**
5. *Victoriceras.*	5. *Radstockiceras.*	5. *Radstockiceras* (22).
4. *Oxynoticeras.*	4. *Victoriceras.*	4. *Oxynoticeras* (17).
3. *Radstockiceras.*	3. *Oxynoticeras.*	3. *Victoriceras* (16).
2. *Gleviceras.*	2. *Guibaliceras.*	2. *Guibaliceras* (11).
1. *Guibaliceras.*	1. *Gleviceras.*	1. *Gleviceras* (9).

The natural order is arrived at by adding the position-marks attained under the five different bases of analysis.

Amaltheus lymensis Wright (pl. xlvi, figs. 1–3 & pl. xlvii, figs. 1–3) cited as *Oxynoticeras lymense* in my Chronological paper, p. 270, would seem not to belong to any of these genera. To be *Oxynoticeras* it should have a suture-line more complicated than that of *O. polyophyllum*, but its skeleton outline is more that of *Guibaliceras*.

Genus Arietites Waagen.

Arietites turgescens, sp. nov. (Pl. XXIX, figs. 2 *a* & 2 *b*; Pl. XXXI, fig. 5.)

Cf. 1864. *Ammonites turneri* Wright (*non* J. de C. Sowerby sp.), 'Amm. of Lias' Proc. Cotteswold Club, iii, pl. ii, fig. 4.
Cf. 1879. *Arietites turneri* Wright (*non* J. de C. Sowerby sp.), 'Lias Ammonites' pl. xii, figs. 1–3; 1881, p. 292.
Cf. 1879. *Ammonites brooki* Reynès (*non* J. Sowerby sp.), 'Mon. Amm.' pl. xliii, figs. 6 & 7.[1]

[1] These three references happen to be all figures of one specimen : see p. 322.

Description.—Serpenticone; platysubpachygyral, latumbilicate to perlatumbilicate, carinati-sulcate, costate, gammiradiate.

Remarks.—This inflated *Arietites* is sufficiently well represented in Wright's figure and description, although Wright's form attained to somewhat greater stoutness at an earlier age. Reynès's shell has similar proportions to Wright's 1879 figure, but is somewhat different in ribbing.[1] The shell now described is neither *A. turneri* nor *A. brooki*, as the proportions stated on p. 298 will show: it is an inflated development of *A. turneri*, and is not intermediate between *A. turneri* and *A. brooki*, as the latter belongs to the compressed stock.

Apart from its geological interest, which will be discussed presently (p. 311), and its biological interest as an inflated *Arietites*, the shell now described is noticeable for a pathological development. On the periphery of the last quarter of the outer whorl the strong keel and furrows suddenly cease, and a rounded venter is produced: the much ventrally-projected radii which accompanied keel and furrows—one of the generic characters of *Arietites*—also suddenly give place to radii crossing the venter with a slight linguiform bend (Pl. XXXI, fig. 5). This change is presumably due to injury, and the injury has brought on highly-accelerated catagenesis of the periphery, but has not affected the strength of the lateral ribs. We know that catagenesis is the reversal of anagenesis, and we know from allied stocks that keel and furrows ultimately die away leaving a rounded venter; also that highly-projected ventral radii will return to a less projected state. But such catagenesis is usually gradual, and comes on with general decay of ornament all over, usually after a period of compression with umbilical contraction. Here the catagenesis is local, and is produced in a sudden jump[2]: the specimen was in a flourishing state, and apparently was on its way (see Wright's example) to produce thicker forms.

I have had by me for many years a considerable series of these pathological specimens, having had hopes of illustrating and discussing them. They should be of more than ordinary interest, because in connexion with the law of tachygenesis, and with the law of catagenesis being the reversal of anagenesis, they might contribute important items of knowledge to the science of pathology.

History of the figured specimen.—From a hard bluish, decomposing to a soft white (chalky) matrix of Lower Lias, out of the excavation for the reservoir of the Bristol Waterworks at Barrow Gurney (North Somerset)—purchased. In the aperture is a small *Xipheroceras* of the *planicosta* style.

[1] But see p. 322.

[2] It is noteworthy that, as yet, there are no known descendants of *Arietites* reproducing the rounded venter of this sudden jump. The nearest analogues are the degenerate Asteroceratés of the *sagittarium* pattern (see Chronological paper, p. 271), and so far as is known they are evolved by gradual change and normal earlier inheritance of characters (tachygenesis) as is the case with other ammonites.

TABLE XV.—PROPORTIONS: *ARIETITES* (*BROOKI* AND *TURGESCENS* SERIES).

brooki, Series.	*Arietites* aff. *plotti* (Reynès). (*Ar. bonnardii* Wright, xi, p. 287).[1]	F. 114,	22,	20,	57.
		T. 110,	22·5,	20,	—.
	Arietites plotti (Reynès). (*Am. plotti* Reynès, xxxvi, 15, 16).[2]	F. 97,	26,	25·5,	53.
	Arietites turneri (J. de C. Sowerby). (*Ammonites turneri* Sowerby, cccclii, top fig.).[3]	F. 79,	32,	[26],	46.
	(*Am. turneri* Reynès, xl, 18, 19).[2]	F. 65,	31,	26,	46.
	Arietites sp. (*Arietites* sp. Lang, from Bed 77).[4]	S. 53,	34,	26?,	40?
	Arietites brooki (J. Sowerby). (*Ammonites brooki* Wright, ii, 5)[5].	F. 92,	37,	27,	34.
	(*Am. brooki* Wright, vi, 4, p. 280)[1]	F. 142,	37,	—,	34.
		T. 140,	39,	28,	—.
	(*Am. brooki* Reynès, xxxvii, 5, 6).[2]	F. 147,	36,	27,	35.
	(*Am. brooki* Sowerby, cxc)[3]	F. 148,	40 ?	—,	35.
turgescens. Series.	*Arietites turgescens*, nov.[6]	S. 171,	33,	32,	45.
	Arietites aff. *turgescens*. (*Ar. turneri* Wright, xii, 1–3)[1] ...	F. 53,	35,	35,	42.
		F. 118,	37,	34,	37.
		T. 115,	35,	33,	—.

Genus ARNIOCERAS Hyatt.

ARNIOCERAS FLAVUM, nom. nov. (Pl. XXXI, figs. 2 *a* & 2 *b*.)

1878. *Arietites semicostatus* Wright (*non* Young & Bird sp.), 'Lias Ammonites pl. i, fig. 7 only.

Description.—Subplaty-subleptogyral; subextremilatumbilicate; periphery fastigate, distincti-carinate; whorls smooth; suture-line simple, external lobe about as long as superior lateral.

Remarks.—A smooth, keeled *Arnioceras*, possibly adult. Arniocerates in the smooth stage have been made types of five species, and names of other species have been applied to them. For consideration now are—

1. 1858, *Ammonites miserabilis* Quenstedt.
2. 1867, *Psiloceras acutidorsale* Hyatt.
3. 1867, *Arnioceras cuneiforme* Hyatt.
4. 1876, *Ægoceras nigrum* Blake.
5. 1878, *Arietites semicostatus* Wright (*non* Young & Bird sp.).
6. 1883, *Ammonites falcaries lævissimus* Quenstedt.

The species now described, however, agrees only with Wright's, judging his figure as depicting a keel, for Hyatt's and Blake's species are both ruled out by their peripheries. *Psiloceras acutidorsale* has 'abdomen prominent, acute,'—no mention of a distinct keel; Blake's *Ægoceras nigrum* has an 'angular front'; and Hyatt's *Arnioceras cuneiforme* is figured with merely a sharply angulate periphery; *Ammonites falcaries lævissimus* is different in proportions, so there remains only *A. miserabilis*, which Quenstedt

[1] 'Monogr. Lias Ammonites.'
[2] 'Mon. Amm.' 1879.
[3] 'Mineral Conchology.'
[4] See Chronological paper, p. 271.
[5] Proc. Cotteswold F. C. vol. iii, 1864.
[6] Where the keel ends.

[illegible]

[illegible]

[illegible]

[illegible] now be given.

TABLE XVI.—PROPORTIONS: ARNIOCERAS, SMOOTH SPECIES.

Periphery angulate.

1. *Arnioceras* cf. *acutidorsale* (Hyatt).				
(*Ammonites miserabilis* Quenstedt, xiii, 27)[2]	F. 26,	22,	20,	60.
(*Am. miserabilis* Quenstedt, xiii, 28)[3]	F. 17·5,	22,	21,	59.
2. *Arnioceras acutidorsale* (Hyatt), ii, 4[4]	F. 32,	26,	—,	54
3. *Arnioceras cuneiforme* Hyatt, ii, 5[4]	F. 20·5,	25,	24?,	55.
4. *Arnioceras nigrum* (Blake).				
(*Ægoceras nigrum* Blake, vi, 6)[5]	F. 20·5,	28,	—,	49.
	T. 19,	27,	26,	—.

Periphery with distinct keel.

1. *Arnioceras* aff. *miserabile* (Quenstedt).				
([illegible] *miserabilis* Quenstedt, pl. [illegible])	[illegible]	[illegible]	[illegible]	[illegible]
2. *Arnioceras miserabile* (Quenstedt).				
([illegible]*ites miserabilis*, Quenstedt, pl. [illegible])	[illegible]	[illegible]		[illegible]
3. *Arnioceras flavum*, nov.				
(*Arietites semicostatus* Wright, i, 7)[7]	F. 28,	26,	—,	52.
([illegible], Pl. XXXI, fig. 2)	S. 25,	27,	20,	51.
4. *Arnioceras lævissimum* (Quenstedt).				
(*Ammonites falcaries lævissi*[illegible] Quenstedt, pl. xiii, fig. 18)[3]	F. 30,	33,	21,	44.

[1] 'Ammoniten d. Schwäbischen Jura' p. 71.
[2] [illegible] [3] *Op.* [illegible]
[4] [illegible] [5] [illegible] 'Yorkshire Lias' [illegible]
[6] *Op.* [illegible] [7] 'Monogr. Lias Ammonites' [illegible]

If these forms were to be combined under one name as *Arnioceras miserabile* without taking account of the differences of periphery and proportions, it is possible that certain facts of geographical and stratigraphical distribution might be overlooked for want of distinctive appellations. It is not yet known that the different forms are of strictly identical dates; and on the geographical distribution something will be said later (p. 314).

Facts of evolution might also be lost without distinctive names. For there seem to be really two lines developing side by side—one in which the periphery proceeds no further than the angulate stage but the whorl increases laterally—in thickness; the other in which the periphery proceeds past the angulate stage to a carina with indications of channels, but the lateral development lags behind—the increase in whorl-thickness is slower. Of the first series 1–3 are morphic equivalents of 1, 2 of the second; 4 of the first is in the same relation to 3 of the second, while 4 of the second stands isolated.

To Hyatt's idea that the smooth forms of *Arnioceras* are derivates of *Psiloceras planorbis* I cannot assent. *Ps. planorbis* and like smooth forms of that genus are catagenetic—post-costate—developments with a degenerating phylloid suture-line. The smooth forms of *Arnioceras* are anagenetic developments—pre-costate—with a ceratitic suture-line, simple because undeveloped. The likeness is deceptive: it is a case of transversal homœomorphy.[1]

The next species well illustrates the precostate character of smooth *Arnioceras*.

History of figured specimen.—From the Lias of Lyme Regis (Dorset)—purchased there. It is yellowish-brown—hence the trivial name—the colour which Sowerby illustrates for his *Ammonites brooki*.[2] This character may perhaps be a means of fixing its exact stratigraphical position. See later, p. 314.

ARNIOCERAS ANAGENETICUM, sp. nov. (Pl. XXXI, figs. 3 *a*–3 *d*.)

Cf. 1889. *Arnioceras semicostatum* Hyatt (*non* Young & Bird sp.), 'Gen. Ariet.' pl. ii, fig. 10 only.—Proportions: F. 34, 26, 26, 51.

Proportions. { S. 24, 33, 25, 44.
{ S. 42, 27, 20(24), 51.

Description.—Serpenticone; subplaty-subleptogyral; subextremilatumbilicate; carinati-subsulcate; mainly smooth, finishing costate, parvinodate.

General details.—The distinctive feature of this species is a prolonged smooth or nearly smooth stage, for over most of this stage capillation and occasional very obscure costulæ may be detected. On the last quarter-whorl are developed what must be regarded as adult or even old-age characters—costæ plain at first, but later on bearing incipient tuberculation—small nodes.

[1] 'Yorkshire Type Ammonites' ii (1913) p. vi.
[2] 'Mineral Conchology' 1818, pl. cxc.

The periphery at the beginning of the last whorl is carinate and tabulate; at the end of it, carinate-subsulcate. Body-chamber just under half a whorl, specimen being presumably complete.

Remarks.—The smooth stage of this species being distinctly keeled connects it with the keeled series of smooth Arniocerates, and it is presumably a development of the *miserabile-flavum* line. The ribs being only slightly reclinate it may reasonably pass into the *Arnioceras-bodleyi* series of costate Arniocerates; less likely into the next species. In the species now described the ribs are an adult or old-age feature, in the costate Arniocerates a juvenile character—an illustration of the law of tachygenesis. In the species now described small nodes make their appearance almost as soon as ribs; but in some lines of costate Arniocerates nodes are long in appearing may not appear at all. The difference in the time of developing nodes may be a means of distinguishing lineages in costate Arniocerates, as the time of carination seems to be among the smooth forms.

History of figured specimen.—From blue Lias Limestone of Lyme Regis (Dorset) purchased there. The test has the same colour as *Arnioceras flavum*. In the matrix is a small example of what is perhaps *Cymbites*.

[Since this paper was read I have obtained the presumed holotype of *Ammonites semicostatus* Young & Bird. It is illustrated in 'Yorkshire Type Ammonites' 1918, pl. cxii.]

ARNIOCERAS FORTUNATUM, sp. nov. (Pl. XXVIII, fig. 4; Pl. XXXI, figs. 4 *a* & 4 *b*.)

Cf. 1883. *Ammonites ceratitoides* Quenstedt, 'Ammoniten d. Schwäbischen Jura' pl. xiii, fig. 8 (not of 'Cephalopoden' 1849, pl. xix, fig. 13).

Description.—Serpenticone; subplatygyral to substenogyral; leptogyral; subextremilatumbilicate; carinate-sulcate; rursisub-recticostate, parvinodate. Smooth stage to about 10 mm. diameter, costulate to about 18 mm., then an injury, costate from about 20 mm. onwards. The costæ are decidedly reclinate and nearly straight on lateral area, sharply projected beyond small nodi, which are situated on the periphero-lateral border. Suture-line simple.

Remarks.—This species is much larger than any *Arnioceras* known to me in literature; but Mr. Tutcher has a fragment of an *Arnioceras* from Radstock which would measure about 5½ inches (140 mm.) in diameter. The species is distinct from *A. bodleyi* (J. Buckman) by its more reclinate, wider-spaced ribs and by a somewhat smaller umbilicus at the same diameter. It might be suggested that the reclinate ribs were due to the injury in the young stage, but it is evident that the specimen entirely recovered from this, and was so little affected that it grew to an unusual size. Mr. Tutcher has Radstock specimens of *Arnioceras* with much reclinate ribs. Also Quenstedt figures a form which has the same

style of reclinate and well-spaced ribbing. Quenstedt's specimen is not, however, quite the same: it is the next step onward; its smooth stage is evidently shorter, its whorl somewhat broader, and its umbilicus rather narrower.

For dimensions of this and comparable species, see below.

History of figured specimen.—Out of a dark (phosphatic?) limestone of the Lower Lias from Paulton, near Radstock (Somerset) —purchased from a workman.

TABLE XVII.—PROPORTIONS: *ARNIOCERAS FORTUNATUM* AND LIKE FORMS.

Arnioceras fortunatum, nov.	S. 62,	26,	—,	54.
	80,	23,	16(18),	57.
	121,	20,	16(17+),	60.
Arnioceras aff. *fortunatum*.				
(*Ammonites ceratitoides* Quenstedt, xiii, 8) [1].	F. 49,	27,	17(21),	51.
Arnioceras bodleyi (J. Buckman).				
(*Ammonites bodleyi* J. Buckman, xi, 7) [2]...	F. 68,	25,	18(20)?,	56.
(*Arietites semicostatus* Wright, i, 4, 5) [3] ...	F. 74,	24,	17,	57.
(*Ammonites ceratitoides* Quenstedt, xiii, 10) [1].	F. 76,	25,	17(19),	58.
(*Arnioceras bodleyi* S. Buckman) [4]	S. 62,	23,	17(21),	57.

CORONICERAS BUCKLANDI (J. Sowerby).

1816. *Ammonites bucklandi* J. Sowerby, 'Mineral Conchology' vol. ii, pl. cxxx & p. 69.

Mr. Tutcher has a large specimen from Keynsham, near Bath (Somerset)—a topotype, for Sowerby's 'Bath and the neighbourhood' doubtless meant Keynsham. He gives the following proportions, S. 493, 26, 32, 55; and Sowerby's figure, allowing for foreshortening, I estimate to give much the same: his figure is presumably reduced to about a quarter of the natural size.

Most interpretations of this species fail to allow for the great thickness of whorl maintained to 20 or more inches in diameter. See Chronological paper, p. 273.

Family DEROCERATIDÆ.

Genus DEROCERAS Hyatt.

DEROCERAS BISPINIGERUM, nom. nov. (P. 294, fig. 7.)

1903. *Deroceras* sp., S. S. Buckman, Q. J. G. S. vol. lix, pl. xxvii, figs. 5 & 6 (holotype).

1914. Bituberculate Deroceratid, Lang, Proc. Geol. Assoc. vol. xxv, p. 321.

Remarks.—This name is for a species already figured in the Society's Journal but without trivial appellation. As Mr. Lang has now found another example 37 mm. in diameter, with the same

[1] 'Ammoniten d. Schwäbischen Jura.'

[2] 'Geology of Cheltenham' new ed. 1844.

[3] 'Monogr. Lias Ammonites' 1878.

[4] Figured in 'Palæontologia Universalis' 1904. No. 36. T^1. The end of the whorl, it should be noted with regard to figs. T^{1a}, T^{1b}, is somewhat swollen with pyrites.

mineral condition, as he has obtained it *in situ* (which fixes the horizon for the first specimen), and, as it marks a definite horizon in the Raasayan, a full name is desirable.

This species is comparable with two of Geyer's, but differs from his *Ægoceras præcursor*, with which it shares the radial linear ornament, by whorl-shape—whorl widest at the periphery—the retention of the inner row of spines, and yet having less whorl-inflation. His *Ægoceras bispinatum* is separable by having a more rounded periphery, a different whorl-shape, more approximate spinicostæ, and less differentiation in spines of the two rows. For references and proportions, see table below.

History of the types.—Holotype, from a bed of Lias yielding pyritized fossils in the neighbourhood of Lyme Regis (Dorset)—purchased there. Paratype, 'in place, bed 94, about 4 feet above *Oxynotus* bed. About 800 yards west of Westhay Water, east of Charmouth,' Dorset; Coll. W. D. Lang, No. 2578. See Table V, facing p. 267.

TABLE XVIII.—PROPORTIONS: *DEROCERAS*, ETC.

Deroceras bispinigerum, holotype	S. 55,	28,	35,	50.
Do. do. paratype	S. 37,	28,	34,	49.
Ægoceras præcursor Geyer [1]	F. 48,	32,	38,	45,
	T. 50,	26,	30,	49.
Ægoceras bispinatum Geyer [2]	F. 55,	30,	35,	46.

Genus MICRODEROCERAS Hyatt.

MICRODEROCERAS DEPRESSUM, nom. nov. (Pl. XXX, figs. 1*a* & 1*b*.)

1867. *Ammonites birchi* Dumortier (*non* J. Sowerby), depressed variety, 'Bassin du Rhône' vol. ii, pl. xli, figs. 1, 2, p. 130.

Remarks.—This name applies to the shell figured by Dumortier, which he notes as different from that figured by Sowerby and A. d'Orbigny. He calls it a depressed variety, and that appellation is retained in the present trivial name. The holotype, however, is an English specimen which agrees with Dumortier's shell, except in one respect—Dumortier's shows peripheral radii (costulæ) nearly straight and parallel; in the English shell the radii connecting tubercles are nearly straight, but the intermediaries have rather more forward bending.

The stouter whorls with a more pronounced umbilical wall, a slightly shorter smooth stage, and a small increase in the number of tubercles to a whorl in middle age, are features of distinction from *Ammonites birchi*.

Proportions are given below (p. 306).

History of the specimens.—Figured specimen (No. 1280) from blue Lias, excavation for reservoir of Bristol Waterworks, Barrow Gurney (Somerset), presented by Mr. J. W. D. Marshall.

[1] 'Ceph. Hierlatz' Abhandl. k. k. Geol. Reichsanst. vol. xii (1886) pl. iii, fig. 27. [2] *Ibid.* pl. iv, fig. 4.

Another example, about same size and matrix, and a smaller specimen with matrix decomposed to light yellow, presented by the late E. Wilson, F.G.S. Another example, matrix soft, decomposed to light blue (purchased): all from the same place. And see note to next species.

MICRODEROCERAS SEPTIGERUM, nom. nov. (Pl. XXX, figs. 2*a* & 2*b*.)

1844. *Ammonites birchii* J. Buckman *pars* (*non* J. Sowerby), 'Geology of Cheltenham' new ed. p. 88.

Description.—Serpenticone; platy-perpachygyral, perlatumbilicate to pachygyral latumbilicate; bituberculate; septituberculate; periphery flatly rounded, subarci-costulate.

Remarks.—This is an inflated development of *Ammonites birchi* by way of the last species (*M. depressum*), but it has not attained to the inflated proportions of the next species (*M. inflatum*), though it has passed that species in the differentiation of the outer tubercles compared to the inner—the character seen at a later date in *Deroceras* (*D. bispinigerum*, p. 302) and later still carried to unituberculation.

This species is best understood by comparison with *M. inflatum*. Its thickness is some 7 per cent. less at 64 mm. diameter, and the periphery is somewhat flatter. The ornament is similar, but the spinicostæ are about 50 per cent. wider apart, and the outer row of spines is shown by the septate areas to be more developed and more differentiated from the inner. The conspicuous septate areas which are somewhat B-shaped suggest the trivial name: the outer (top) loop is broadly, and the inner narrowly, elongate with a thin connecting area—thus the partition extended not only under the spines, but also under the connecting rib.

Proportions are tabulated below (p. 306).

History of the figured specimen.—The original label, skeleton printed, on the specimen reads: 'Name *A. Birchii*, Loc. *Lias, Cheltenham*, Col. by *J. Buckman*,'—the words in italics filled in in his handwriting. The matrix is light blue with crinoid-stems, small gastropods, small lamellibranchs, and broken organisms. See below, p. 312.

[Note.—Since this paper was written I find that I have overlooked another of my father's specimens of *Ammonites birchii* (S. B. coll. No. 2115). It has a quite different matrix—blue and pyritic; but bears the same label, which thus may mean 'close to Cheltenham' rather than 'Cheltenham district': see below, p. 312. Its proportions are S. 72, 28, 29 (31), 49; S. 114, 26, 28 (29), 51. Spines are approximate and somewhat small—38 on last row of outer whorl. It is an example of *Microderoceras depressum*, see above. On one side is an impression of a portion of another *Microderoceras*, of about the same size, showing obsolescence of spines, of interest in connexion with remarks below, p. 307.]

MICRODEROCERAS INFLATUM, sp. nov. (Pl. XXVIII, fig. 3; Pl. XXIX, fig. 1.)

Description.—Serpenticone; platy-perpachygyral, perlatumbilicate to subplaty-pachygyral, perlatumbilicate; bituberculate, septituberculate; periphery rounded, subarcilineate.

General details.—A much inflated development of *Ammonites birchi*, beginning with a similar smooth stage, rapidly developing bituberculate, whereof presently the outer row becomes rather stronger than the inner. Beneath spines and connecting rib there is a septum of subspatulate shape. Close-set hair-like lines occupy the interspaces and the arching periphery, which latter they cross with a slight forward bend.

Distinction.—The proportions (see below, p. 306) distinguish this from preceding species: it attains at one time an inflation of 50 per cent. of the diameter, but afterwards declines as if commencing to return to the *birchi* style.

Remarks.—According to indications of test on the periphery the specimen had another complete whorl at least. Its diameter may be roughly estimated, from the fact that from the centre to the farthest periphery is 55 per cent. of the diameter of the last whorl present: therefore the maximum radius becomes 45 per cent. of the diameter of the next half-whorl, which being thus ascertained, its maximum radius becomes the basis, roughly 45 per cent. of the second half-whorl. The indications of test on the periphery give umbilical width of 54 and 62 per cent. of the respective diameters (164 mm. and 198 mm.) so ascertained: these umbilical widths are perhaps too great, because possibly the 55 per cent. basis was not maintained; and so the diameters are perhaps understated—the whorl becoming thinner and broader. The umbilicus is expanding, as the inner line is leaving the outer spine-line.

As this specimen may be reckoned to have attained a diameter of 200 mm. or more, it was, considering its inflated proportions, altogether a much larger growth, had a greater bulk, than *Ammonites birchi*, though A. d'Orbigny does record a diameter of 240 mm. for his specimen. The species now described possibly represented the acme of development in *Microderoceras*; but some of the later Derocerates far exceeded these dimensions—some of the Radstock giants collected by Mr. Tutcher and myself from the *leckenbyi* bed attaining to 360-380 mm. (14-15 inches) in diameter.

History of the figured specimen.—From hard light-blue Lias weathered to light yellow and soft [white in places?], from excavations for reservoir of Bristol Waterworks, Barrow Gurney (Somerset)—purchased.

MICRODEROCERAS RHODANICUM, nom. nov.

Ammonites heberti Dumortier (*non* Oppel), 'Bassin du Rhône' vol. iii (1869) pl. viii, figs. 5-6 & p. 66.

Remarks.—This name is for Dumortier's species quoted above,

which is not Oppel's species, for that was founded on *Ammonites brevispina* D'Orbigny (*non* Sowerby). Its proportions are different. Dumortier's is a thicker form; D'Orbigny's is a further stage on in compression and degeneration: it gets back to the smooth stage.

TABLE XIX.—PROPORTIONS: MICRODEROCERATES.

1.	*Microderoceras birchi* (Sowerby).					
	(*Ammonites birchi* Sowerby, pl. cclxvii)[1]	F. 204,	25,	[26?],	57.
	(*Ægoceras birchi* Wright, pl. xxiii)[2]...	F. 160,	22,	23,	58.
2.	*Microderoceras depressum*, nov.				
	(Holotype, Barrow specimen)	S. 75,	29,	32,	47.
	(*Ammonites birchi* Dumortier, xli, p. 130)[3]	F. 197(94),	28,	29,	51.
		T. 197,	28,	31,	50.
	Microderoceras septigerum, nov.				
	(*Ammonites birchi* J. Buckman)	S. 42,	33,	43,	45.
		S. 89,	35,	40,	42.
	Microderoceras inflatum, nov.	S. 64,	34,	50,	45.
		S. 131,	30,	38,	44.
3.	*Microderoceras bispinatum* (Geyer).				
	(*Ægoceras bispinatum* Geyer)	F. 55,	30,	35,	46.
	Microderoceras rhodanicum, nov.	F. 35,	32,	—,	44.
	(*Ammonites heberti* Dumortier).	T. 35,	31,	42,	37.
		F. 77,	34,	—,	45.
		T. 74,	32,	29,	45.
	Microderoceras heberti (Oppel).				
	(*Ammonites brevispina* D'Orbigny, lxxix)[4]	F. 74(47),	32,	24,	45.
		F. 140(90),	32,	24,	47.
		T. 140,	31,	25,	47.
	Microderoceras roberti (Hauer).				
	(*Ammonites roberti* Hauer, iii)[5]	T. 97,	36,	23,	40.

Microderoceras septigerum and *M. inflatum* are species sufficiently alike to make it probable that they indicate beds of the same date. More will be said on this point presently (p. 311). Curiously enough, I have not found in literature anything really like these inflated forms. The most comparable species are *Ægoceras præcursor* and *Æ. bispinatum* Geyer, possibly of basal Raasayan, *Deroceras bispinigerum* (p. 302), low in Raasayan, *Microderoceras rhodanicum* (p. 305), presumably top of Raasayan (*leckenbyi*). All differ in proportions from the inflated forms, as Tables XVIII & XIX show.

The placing of certain bituberculate species to *Microderoceras* and others to *Deroceras* must be regarded as conventional. I am not prepared at present to state the difference between them: the study necessary for that might delay this Appendix for several years; and it is a biological matter.

This, however, may perhaps be said: various branches of *Microderoceras* may be noted:—

1. The *birchi* set—the *A. birchi* of Sowerby, Wright, D'Orbigny,

[1] 'Mineral Conchology.'
[2] 'Monogr. Lias Ammonites.'
[3] 'Bass. Rhône,' vol. ii.
[4] 'Pal. franç.: Terr. Jur. Céph.'
[5] 'Capric.' Sitzungsber. k. Akad. Wissensch. Wien, vol. xiii (1854) p. 94.

and others with the forms to which Quenstedt has given names—*M. nodosissimum*,[1] *M. enode*,[2] *M. gigas*.[3] In this set catagenesis to smooth occurs without an inflated stage and without much umbilical contraction.

2. The *inflatum* set: This starts from *M. depressum*, an offshoot of the *birchi* set while in its prime, and it continues anagenesis until a maximum whorl-inflation of about 50 per cent. is reached, after which decline sets in. Between *M. depressum* with 32 per cent. of inflation and *M. inflatum* with 50 there is evidently room for another species: *M. septigerum* comes here, but does not quite satisfy as a link, because of its more distant ornament.

3. The *heberti* series: This branches off from *M. depressum*, perhaps, or some morphic equivalent; but it is a series much later in date. It goes through an inflated period similar to the last, running up to 42 per cent. Then it rapidly declines, broadens and compresses the whorl, becomes smooth, and presumably ends off in a smooth subplatycone series—such as *Ammonites roberti* Hauer,[4] Reynès,[5] *A. lorioli* Hug,[6] *A. steinmanni* Hug,[7] *A. plumarius* Dumortier.[8] Specimens with the catagenetic characters of those just named are in Mr. Tutcher's cabinet from about *leckenbyi* of Radstock: they have a bituberculate Microderoceratan stage in inner whorls and a Microderoceratan suture-line.

4. The *Deroceras* stock:—This would branch like the last from some morphic equivalent of *M. depressum*, an early stage being represented by *Deroceras bispinigerum*. This line does not go through an inflated stage while bituberculate, but it loses this character early, dropping the inner row of spines, compensating by enlarging the outer row and broadening the periphery, producing in some cases in the unituberculate stage not true inflation but forms broad in the venter with much divergent sides—a method of producing cadicones ultimately. But there must be several lineages now combined in *Deroceras*—and in some of them the morphogeny must be complicated, with apparently alternations of anagenetic and catagenetic stages of ornament.

(*c*) Geological Inferences from the Described Species.

Domerian. *Leptaleoceras* is interesting for its rarity. Among the hundreds of British Domerian (Marlstone Series) ammonites that have passed through my hands, I remember only the three specimens now dealt with; and I can recall but few cases of similar Hildoceratids.[9] Mr. Spath says that 'even in the British Museum collections Mesoliassic Hildoceratids are almost unrepresented.'[10]

1 'Ammoniten d. Schwäbischen Jura' xviii, 7, *Am. birchi nodosissimus*.
2 *Ibid.* xviii, 9, *Am. birchi enodis*.
3 *Ibid.* xviii, 13, *Am. birchi gigas*.
4 *Loc. jam cit.*
5 'Mon. Amm.' pl. xxx, figs. 13 & 14 (copy of Hauer).
6 Abh. Schweiz. Pal. xxvi (1899) pl. viii, fig. 1 & pl. ix, fig. 2.
7 *Ibid.* pl. ix, figs. 1 & 2.
8 'Bassin du Rhône' vol. iii (1869) pl. xvii, figs. 1–3.
9 Excluding *Seguenziceras*.
10 *Op. jam cit.* p. 547.

Such Hildoceratids find their home in the Mediterranean area: whether their rarity here is due to stratal failure or inequality of zoological distribution is for future work to determine.

An attempt to ascertain the position of *Leptaleoceras* in the Domerian may be made by comparison of its matrix with that of other Ammonites. Taking the Gloucestershire area first—the matrix of *A. nautiliformis* J. Buckman,[1] from a neighbouring Marlstone eminence, Alderton-Dumbleton, a few miles north of Gretton, is light blue, compact, arenaceo-calcareous (micaceous ?) non-oolitic—very suggestive of the 'bluish gray calcareous grit' mentioned for a bed of 'Marlstone'[2] (lower Domerian, below the Rock-Bed). The matrix of *Leptaleoceras* is blue, less compact, calcareous and shelly. That of specimens of *Amaltheus armiger*[3] (*Am. amaltheus spinosus* Quenstedt, *pars*) from Gretton and Alderton is feebly blue, oolitic, very shelly; while that of Paltopleurocerates from the latter place varies from somewhat similar, not so shelly, to yellow, not shelly, not oolitic.

On the principle that the blue colour and the arenaceous character are indices of lower beds, the following Gloucestershire sequence may be surmised:—

5. *Paltopleuroceras.*
4. *Amalthei* (spinous forms).
3. *Leptaleoceras.*
2. *A. nautiliformis.*
1. —— ?

In regard to South Petherton, colour fails to make distinction between the matrices of such ammonites: all are a yellowish, more or less ironshot oolite, with only the distinction of larger browner limonitic grains in the cases of the Amaltheids. The absence of blue colour and of micaceous grains with presence of ironshot oolite seems to show that all come not lower—and it may be in, the Rock-Bed—equivalent to Bed 4. 8 to 12 feet thick, of Woodward's section from the neighbourhood[4]—this Rock-Bed being some 150 feet from the base of the Marlstone Series of which the lower 100 feet is described as 'blue and grey micaceous marls.' In this Rock-Bed it may be assumed that the Amaltheids occupy the higher part, and the other ammonites the lower; and now that the Gloucestershire district has suggested somewhat of a clue, perhaps the differentiation of the Somerset Rock-Bed into zones can be made: there is room enough for several, and the need is obvious.

This interpretation with regard to *nautiliformis* and its matrices would mean, if correct, that in the Ilminster district of Somerset the Marlstone Rock-Bed began earlier than in Gloucestershire;

[1] 'Yorkshire Type Ammmonites' 1911, No. 37.

[2] 'Geology of Cheltenham' new ed. 1844, p. 38, Bed 2.

[3] 'Yorkshire Type Ammonites' 1911, p. 25 d. As one finds this and like spinous *Amalthei* labelled *Am. spinatus* on occasion, a clue may be afforded to some old records.

[4] 'Lias of Engl.: Jur. Rocks' vol. iii, Mem. Geol. Surv. 1893, p. 202.

but much variation in this respect may be expected as well as, the more minutely subdivision is carried on, a great increase in local non-sequences.

The position of the *Leptaleoceras* and *A. nautiliformis* horizons in regard to the faunal sequence discussed in the stratigraphical portion of this paper (p. 260), may be surmised to this extent—they are pre-*gibbosa*—a spinous species near to, perhaps as used by Monestier including, *Amaltheus armiger*. Whether they are pre- or post-*algovianum* as now restricted is uncertain; but it may be surmised that they do not correspond to this *algovianum* horizon, because the localities yielding the respective faunas seem to be geographically separate.

Evidence for other pre-*gibbosa* horizons in this country and their relation to the Mediterranean sequence will chiefly depend on certain Amalthei, Lytocerata, and an occasional Hildoceratid. On the Dorset Coast very low down in the Domerian—in the strata just above the Three Tiers—are Amalthei of the *clevelandicus* pattern, and the same occur low down in marls at Lightpill, near Stroud (Gloucestershire). Large Amalthei of the *stokesi* pattern occur in sandy strata at South Petherton—perhaps the *A. margaritatus* of Woodward's Bed 2[1]; but whether this is pre- or post-*algovianum* in its restricted sense is uncertain. The original *Ammonites stokesi* came from the Dorset Coast; but there is the same doubt about its position: one can only judge from the colouring of Sowerby's plate that it is from blue marls. Fine Lytocerates occur in the Marlstone Series at Dudbridge, near Stroud, and at two horizons on the Dorset Coast: there are various species, recorded incorrectly as *A. fimbriatus*. Day cites the good specimens from his *Margaritatus* stone[2] where I have found them, and he places others lower.[3] Whether the Dudbridge species are on the same horizon as either of the Dorset species cannot yet be said: there may be three horizons.

All this evidence, faulty though it may be, seems to suggest that there are the following pre-*gibbosa* horizons in the English Domerian to deal with:—

Leptaleoceras.
Sphærocones (*A. nautiliformis*).
Amalthei (of *stokesi* pattern).
Seguenziceras (and small Amalthei).
Lytocerata.
Amalthei of *clevelandicus* pattern.
Lytocerata.

These divisions may not all be separable, and it is not claimed that they are in correct descending order; but a table of some sort is required as a preliminary to making out our home sequence. Only when that is understood will it be possible to correlate with the Mediterranean sequence, and bring all into one hemeral time-scale.

[1] *Loc. cit.*
[2] Q. J. G. S. vol. xix (1863) p. 292.
[3] *Ibid.* p. 291.

Hwiccian–Wessexian.—The importance of the giant *Acanthopleuroceras* is that during considerable collection in the brickyards of the Cheltenham district nothing at all approaching the size of this specimen and of another fragment, *Acanthopleuroceras gigas* (Quenstedt),[1] nearly as large, rewarded my efforts. These specimens were found by the late Rev. Dr. F. Smithe, F.G.S., during the making of the Banbury & Cheltenham Railway at Leckhampton; and the inference is that a stratum different from any of the brickyard exposures must have been cut through. Whether the stratum belongs to any of the *Acanthopleuroceras* horizons discovered by Mr. Lang on the Dorset Coast, or whether it is distinct from them is a point towards which the attention of future workers should be directed.

The local distribution of *Acanthopleuroceras* in the Cheltenham district seems to indicate two separate horizons, apart from the horizon of the giant forms. Battledown near Cheltenham yields mainly thin species; Leckhampton Station near Cheltenham and Hucclecote near Gloucester yield chiefly stout-whorled species. Further afield Northamptonshire and Radstock yield the thin species—solely, I think, more commonly at any rate. Hitherto these *Acanthopleuroceras*-yielding strata have been reckoned as all in the same zone, but it is now evident that more investigation is required.

In the Cheltenham district a great variety of *Acanthopleurocerata* are found, but rarely otherwise than as body-whorl fragments, which makes their specific identification difficult.

I cannot call to mind anything in literature of the size of the large *Acanthopleuroceras* (260 mm.). Quenstedt's *A. gigas* (pl. xxxv, fig. 14) I estimate at about 170 mm.; his 'largest fragment' (fig. 15) may go up to 200 mm.: the Leckhampton fragment—a body-whorl—reaches 244 mm. in diameter, however. Dumortier's *Ammonites flandrini*[2] measures 202 mm.; but this is a species of quite a distinct type, special perhaps to the South of France. Würtemberg, then, is the only area at all congruous with Gloucestershire in regard to these large forms; and it would seem, if these large forms occupy a distinct horizon, that this horizon has been preserved in areas limited and isolated geographically.

Raasayan.—*Deroceras bispinigerum* marks a *Deroceras* horizon below the main outbreak of Echiocerata. It is interesting as a representative of the bituberculate ancestor of the unituberculate *armati*, and shows the obsolescence of the inner row of tubercles.

Deiran.—The species of *Radstockiceras* and *Gleviceras* are chosen as representatives of the faunas of the Radstock and Gloucestershire Oxynotoid horizons, now separated from the *oxynotum* horizon; but there are several other species in the latter area

[1] 'Ammoniten d. Schwäbischen Jura' pl. xxxv, figs. 14 & 15.
[2] 'Bassin du Rhône' vol. iii (1869) pl. xiv.

and quite a considerable number in the former which require investigation: they do not necessarily belong to the present genera. In fact, the Oxynotoids appear to represent the catagenetic terminals of many different lineages, of which the majority came into view suddenly in the European Deiran without any ancestry. Only *Ammonites oxynotus* Quenstedt, and *A. oxynotus* Dumortier, two quite different species, seem to have traceable ancestors—the former being connected with a tuberculate [1] and the latter with *Arietites* of the *fowleri-collenottii* pattern.[2]

The placing of the Radstock Oxynotoid fauna later than the Gloucestershire one (*Gleviceras*) is a surmise not yet proved; but their difference in species shows that they are distinct in date. To place the Radstock fauna before the Gloucestershire one would involve the supposition of another non-sequence in Gloucestershire.[3] *Gleviceras* belongs to a distinctly higher horizon than the *oxynotum* beds in Gloucestershire: but, if that were not known, the absence of *Gleviceras* from Würtemberg, where *A. oxynotus* is conspicuous, would be presumptive evidence of a difference of date.

It is notable that no specimens of the Radstock Oxynotoid fauna are figured by Quenstedt, and only two examples which have the aspect of constituents of the *Gleviceras* fauna—*Ammonites guibalianus* Quenstedt, 'Ammoniten d. Schwäbischen Jura' pl. xxviii, figs. 3 & 4—not from any *oxynotus* locality, and from a higher horizon (Lias γ). Pompeckj has named them *Oxynoticeras paradoxum*, and places them in *jamesoni* [*leckenbyi?*] zone. They have neither suture-line nor ribbing of *Gleviceras*; and not the ribbing of *Guibaliceras*. Present experience would suggest that their position may be due to derivation.

Mercian–Lymian.—The Barrow Gurney fauna (*Arietites turgescens*, p. 296, and *Microderoceras inflatum*, p. 305) is congruous with that of Bredon (Worcestershire), certainly as regards the *Arietites* and presumably with regard to the *Microderoceras* (see below, p. 312). But this special fauna is not known from intermediate areas, is absent from Dorset and also from Yorkshire so far as my experience goes. Dumortier shows a partly comparable *Microderoceras* fauna, but not *Arietites*; Reynès shows *Arietites*, but not any *Microderoceras* of the style required.[4] Quenstedt shows nothing comparable.[5] A first inference may

[1] See 'Yorkshire Type Ammonites' i (1909) p. 7 b.

[2] To these may now be added *Gleviceras*, see above, p. 292.

[3] See p. 272.

[4] But Reynès is unsafe: his specimens are from many areas; and see p. 322.

[5] One can in the main only go by what is published. I know from my own and other collections that a great mass of new material is unpublished. I write with some knowledge of that, although memory necessarily has its limitations in this respect, owing to the difficulty of fixing new forms in one's mind because of their lack of names. Even photographs help little without names to serve as tags for the memory. But, if similar conditions obtain on the Continent, then of course the statements made above might be invalidated. On the other hand, Continental Ammonitology is far more complete in many areas than is the British.

certainly be drawn, that the special *Microderoceras–Arietites* fauna did not occupy the horizon of either *turneri* or *birchi*, otherwise they should be found in the areas where those species occur; and a second inference may more tentatively be made—that the *Microderoceras* and *Arietites* did not occupy the same horizon.

If it were possible to proceed on strictly biological lines, then a solution would be quite easy; but biological and geological position are not always in accord: *Xipheroceras* above *Microderoceras*, *Paltopleuroceras* later than *Amaltheus*, *Hildoceras* after *Harpoceras* in geological position, when they should respectively precede biologically. But these are distinct genera: in regard to species, *Harpoceras exaratum* below *H. falciferum*, *Hildoceras bifrons* below *H. semipolitum*, *Arietites turneri* below *A. brooki*, and this again much below *A. denotatus*, show very well the agreement of geological position and biological development.

In the present case the assumption of the agreement of biological and geological position is all that there is to go upon. No record of the Barrow exposure seems to have been made. Specimens were very few, so I understand, for the great area opened up; and what have been saved were only the finds which the navvies took the trouble to bring home with them.

The matrix of the Barrow Gurney exposure is a hard blue Lias, which weathers or decomposes to a soft white, almost chalky substance. This matrix is quite unlike any other with which I am acquainted in the South-West, and it would serve well to distinguish Barrow specimens. I find, however, that some specimens in my father's Cheltenham collection show a similar matrix, perhaps rather more cream-coloured; and Wright says of his *Arietites turneri* [*A.* aff. *turgescens*]:

'The specimen figured was collected from a light-coloured clay and limestone in the deep cutting of the Bristol & Birmingham Railway, near Bredon [Worcestershire], associated with *A. Bonnardii*, d'Orbigny, [*Arietites* aff. *plotti* (Reynès)], *A. semicostatus*, Y. & B., [*Arnioceras bodleyi* (J. Buckman)], and several other mollusca, with many fragments of the stems and side arms of *Pentacrinus tuberculatus*, Miller, and *Cidaris Edwardsii*, Wright.'[1]

The character of matrix and the remarks about the *Pentacrinus* well fit the condition of *A. birchi* J. Buckman (*Microderoceras septigerum*); and, though it is labelled Cheltenham, yet Bredon is quoted as a locality for *A. birchi*,[2] and I suspect that the label 'Cheltenham' possibly denoted in such cases 'Cheltenham district,' just as 'Vale of Gloucester' was possibly used to include Bredon. Judging by the light-coloured matrix it may be suggested that from Bredon came my father's holotype and various paratypes of *Ammonites halecis*, the figured specimen and another with perhaps a third of his *A. erugatus* (*Agassiceras*), the specimen he called *A. costatus* (*Agassiceras*), two paratypes of his *A. bodleyi*, and the present holotype of *Microderoceras septigerum*.

[1] Proc. Cotteswold Nat. F. C. vol. iii (1864) p. 177, repeated in 'Monogr. Lias Ammonites' 1881, p. 293; see below, (*e*) p. 318.

[2] 'Geology of Cheltenham' new ed. 1844, p. 88.

Turning now to the biological argument—the biological facts are: 1, *Microderocerata* which are developments of *M. birchi*; 2, *Arietites* which are developments of *A. turneri*: the geological facts are a special matrix for these developments and the position of *M. birchi–A. turneri* on the Dorset Coast: the geographical facts are the presence of the special fauna (and a distinctive matrix) only at isolated places in England, the absence of the fauna from well-known, much-searched localities, and its very limited range upon the Continent.

On these various grounds it may be suggested that the full Mercian–Lymian sequence, instead of being

3. *Arietites brooki*,
2. *Arietites turneri*,
1. *Microderoceras birchi*,

is rather

5. *Arietites brooki*,
4. *Arietites turgescens* (+*A.* aff. *turgescens*),
3. *Arietites turneri*,
2. *Microderoceras inflatum*+*M. septigerum*+*M. depressum*,
1. *Microderoceras birchi*.

This involves the supposition of non-sequences between *birchi* and *turneri* and again between *turneri* and *brooki*, on the Dorset Coast and over other wide areas; but it may be unnecessary to suppose a non-sequence at Barrow for, I think, *turneri* forms were found there. Then the absence of *Arietites brooki* and *Microderoceras birchi* from Barrow might be explained by supposing that the excavation began below the *brooki* bed, and did not go so deep as *birchi*; but other explanations are possible: the area just north of the Mendips was in constant movement.

Another suggestion may be made: that the sequence is

5. *Arietites brooki*.
4. *Arietites turgescens*.
3. *Microderoceras inflatum*.
2. *Arietites turneri*.
1. *Microderoceras birchi*.

This would require only one non-sequence at Lyme Regis, and would meet the case if the true *A. turneri* has not been found at Barrow. This sequence shows faunal repetition such as that found in the Raasayan and in the Hwiccian-Wessexian. Nos. 3 and 4 might be called the Barrow Beds.

In the first case the division between Mercian and Lymian would be drawn between 2 and 3. In the second case, however, it would seem desirable not to draw it between 2 and 1 as proposed earlier in this paper (pp. 271, 274), but to draw it below 1, to prevent divorce of the Microderocerates.

In the case of Bredon there is evidence that earlier faunas were uncovered than at Barrow; and there is reason to suppose that they were found in the peculiar chalky Lias, also that there was

not a non-sequence due to lack of *turneri* beds, for the species cited by Wright as *A. bonnardii* is possible evidence for them.

The true *birchi* beds were presumably present—on the supposition that Wright was referring to the true *birchi* or a very near form, and not to *Microderoceras septigerum*, when he says 'I have several specimens [of *Ægoceras birchii*] which were collected from the railway-cutting near Bredon.'[1]

The evidence for an *Arnioceras* fauna being there and occurring in a chalky matrix has already been given; the same details refer to *Agassiceras*, see above, p. 312, to which may be added that Wright figures a large *Agassiceras* from Bredon.[2]

Lymian.—*Arnioceras* is in the main a genus easy to recognize from other Arietidæ, with its straight sharp ribs and smooth inner whorls: the only difficulty may be with body-chamber fragments. But the species of *Arnioceras* are numerous and not easy to separate; yet for the detailed work now required such recognition will be necessary, in order to see what the succession of species is in time. Old records, where the various species of *Arnioceras* are just cited as *Ammonites semicostatus* without further distinction, serve but a limited, and it may be a somewhat misleading, purpose. For there is reason now to be sceptical whether the placing as isochronous of *semicostatus* beds—that is beds containing *Arnioceras*—is really correct. Faunal repetition and non-sequences may have been overlooked.

Of the species now figured the characters are sufficiently obvious: *Arnioceras flavum* is a carinate smooth form, *A. anageneticum* shows the beginning of ribs, *A. fortunatum* is almost wholly ribbed, distinguished by its markedly-reclinate somewhat distant costæ.

Thirteen species of *Arnioceras* are enumerated from the Whitby district of Yorkshire,[3] and (speaking from memory) all of them are more or less distinct from the species now figured. In Lincolnshire there is a rather heavy form with strong ribs usually called *Ammonites geometricus* Oppel, if and when distinguished from *A. semicostatus*. There may be more than one species involved; but the shells are of very distinct character. This form (or these forms) are constant among all series of Lincolnshire Lower Lias ammonites; but from other British localities they are lacking, or only occur exceptionally.

From the Cheltenham district *Arnioceras bodleyi* seems to be the special form; it is not quoted from Yorkshire in the list cited above; it occurs in Würtemberg, but can hardly be usual there, for only a poor fragment is figured by Quenstedt, see p. 302.

Arnioceras fortunatum is known to me at present only from

[1] Proc. Cotteswold Nat. F. C. vol. iii (1864) p. 179, repeated in 'Monogr. Lias Ammonites' 1882, p. 333; and see below, (*e*) p. 319.

[2] Proc Cotteswold Nat. F. C. vol. iii (1864) pl. ii, fig. 1, refigured in 'Monogr. Lias Ammonites' 1878, pl. viii, figs. 1, 2, *Arietites sauzeanus*: below, (*e*) p. 321.

[3] 'Geol. Whitby' 2nd ed. Mem. Geol. Surv. 1915, p. 98.

Radstock, but Quenstedt figures an approximate form. *A. anageneticum* is a Dorset shell: something similar is figured by Hyatt from Semur[1]; but nothing like either is figured from Würtemberg.

The distribution of the smooth forms is interesting. Yorkshire yields an angulate species and Dorset a carinate one, while no smooth forms are recorded from the Cheltenham area. Neither of the English smooth forms is shown for Würtemberg nor Semur: both yield less advanced angulate and carinate forms, and the former a more advanced carinate, see p. 299. The Rhone Basin seems to lack smooth forms altogether.

It is for future work to determine, on the one hand, whether such differences are due to incompleteness of records and collections or to want of discrimination: on the other hand, whether they are due to chronological (stratigraphical) or geographical causes.

Arnioceras fortunatum is interesting for its size. Now bigness seems to be a character of the ammonites of the Radstock district at several dates of the Lias. Roughly speaking, much the largest British examples of *Arnioceras*, the Oxynotoids, *Echioceras*, *Deroceras*, *Phricodoceras*, and *Uptonia* are all from the Radstock district, and yet its remarkable ammonite fauna is almost unknown in British literature. To these may be added, from the neighbourhood, *Vermiceras* 18 in. (Wright, Monogr. p. 273, *Arietites conybearei*), the most massive *Coroniceras* (*C. bucklandi*), the most bulky *Microderoceras*, the largest *Arietites*. In some cases this phenomenon of local bigness is due to the presence in the district of special strata which have presumably been destroyed in other areas; but is this the whole explanation?

I conclude this palæontological survey with the impression that the principal need of British Jurassic stratigraphy at present is palæontological work—the figuring of the large amount of material which has accumulated.

(*d*) Synopsis and Index Details.

Below is a Synopsis of newly-described or named genera and species—new names being in **heavy type**. The index details are given with the following contractions:—

T.d. Type-description, original description (protolog).
T.f. Type (original) figure (protograph).
Nom. When and where the present trivial name was given.
T.l. Locality which furnished the type.
Hor. Geological position—in words of original description, or label.
Date, Age and hemera (η) as accurately as can be surmised.
Coll. In whose collection when described, or present resting-place, if known.
Form. Proportional formula—that which seems most representative, if that of more than one size of holotype has been given.

[1] 'Gen. Ariet.' 1889, pl. ii, fig. 10, *Arnioceras semicostatum* Hyatt.

The details so given refer to the holotype, or, in default, to the lectotype only. Plate or page quoted without reference refers to the present paper.

Acanthopleuroceras **rursicosta.**

T.d. P. 286.
T.f. Pl. XXVI, fig. 4.
T.l. Leckhampton, Cheltenham (Gloucestershire).
Hor. Middle Lias clays.
Date, Hwiccian–Wessexian.
Coll. Author.
Form. 360, 28, 20, 48.

Arietites **turgescens.**

T.d. P. 296.
T.f. Pl. XXIX, fig. 2; Pl. XXXI, fig. 5.
T.l. Barrow Gurney (Somerset).
Hor. Barrow Beds of Lower Lias.
Date, [Mercian, post-*turneri*].
Coll. Author, No. 833.
Form. 171, 33, 32, 45.

Arnioceras **anageneticum.**

T.d. P. 300.
T.f. Pl. XXX, fig. 3.
T.l. Lyme Regis (Dorset).
Hor. Lias Limestones.
Date, [Lymian, *Arnioceras* η].
Coll. Author, No. 728.
Form. 42, 27, 20(24), 51.

Arnioceras **flavum.**

T.d. P. 298.
T.f. Pl. XXXI, fig. 2.
T.l. Lyme Regis (Dorset).
Hor. Lias Limestones.
Date, [Lymian, *Arnioceras* η].
Coll. Author.
Form. 25, 27, 20, 51.

Arnioceras **fortunatum.**

T.d. P. 301.
T.f. Pl. XXXI, fig. 4.
T.l. Paulton, Radstock (Somerset).
Hor. Lower Lias [phosphatic bed],
Date, Lymian, *Arnioceras* η.
Coll. Author, No. 936.
Form. 80, 23, 16(18), 57.

Deroceras **bispinigerum.**

T.d. S. S. Buckman, Q. J. G. S. vol. lix (1903) p. 460.
T.f. *Ibid.* Pl. xxvii, figs. 5 & 6.
Nom. P. 302.
T.l. [Charmouth], Lyme Regis (Dorset).
Hor. Lias with pyrites.
Date, Raasayan, *bispinigerum* η.
Coll. Author, No. 591.
Form. 55, 28, 35, 50.

Gleviceras, genotype, *G. glevense* paratype (p. 289, Pl. XXVIII, fig. 2).

Gleviceras glevense, holotype.

T.d. P. 289.
T.f. Pl. XXVIII, fig. 1.
T.l. Cheltenham (Gloucestershire).
Hor. Lower Lias Shales [above *oxynotum*].
Date, [Deiran, *Gleviceras* η].
Coll. Author.
Form. 128, 51, 26, 14.

Guibaliceras, Genotype, *Am. guibalianus* D'Orbigny (p. 293).

Leptaleoceras, Genotype, *L. leptum* holotype (p. 284).

Leptaleoceras leptum.

T.d. P. 285.
T.f. Pl. XXVI, fig. 1.
T.l. South Petherton (Somerset).
Hor. Middle Lias Marlstone [Rock-Bed].
Date, [Domerian, pre-*gibbosa*].
Coll. Author, No. 1113.
Form. 66, 24, 16, 52.

Microderoceras **depressum.**

T.d. P. 303.
T.f. Pl. XXX, fig. 1.
T.l. Barrow Gurney (Somerset).
Hor. Barrow Beds of Lower Lias.
Date, [Mercian–Lymian, post-*birchi*].
Coll. Author, No. 1280.
Form. 75, 29, 32, 47.

Microderoceras **inflatum.**

T.d. P. 305.
T.f. Pl. XXVIII, fig. 3; Pl. XXIX, fig. 1.
T.l. Barrow Gurney (Somerset).
Hor. Barrow Beds of Lower Lias.
Date, [Mercian–Lymian, post-*birchi*].
Coll. Author, No. 1281.
Form. 64, 34, 50, 45.

Microderoceras **rhodanicum.**

T.d. Dumortier, 1869, vol. iii, p. 66, *Am. heberti.*
T.f. *Ibid.*, Pl. viii, fig. 5.
Nom. P. 305.
T.l. Saint-Fortunat, South of France.
Hor. Lias moyen, zone à la *belemnites clavatus*, Couches à *Am. armatus.*
Date, [Raasayan, *leckenbyi* η].
Coll. Dumortier.
Form. T. 74. 32, 29, 45.

Microderoceras **septigerum.**

T.d. P. 304.
T.f. Pl. XXX, fig. 2.
Loc. Cheltenham [District], Gloucestershire [Bredon, Worcestershire].
Hor. Lower Lias Shales [with Pentacrinites].
Date, [Mercian–Lymian, post-*birchi*].
Coll. Author, No. 688.
Form. 89, 35, 40, 42.

Radstockiceras, Genotype, *R. complicatum* holotype (p. 287).

Radstockiceras complicatum.

T.d. P. 287.
T.f. Pl. XXVII, fig. 1.
T.l. Radstock (Somerset).
Hor. Lower Lias with Oxynotoids.
Date, Deiran, *Radstockiceras* η.
Coll. Author, No. 2768.
Form. 186, 54, 25, 11.

Victoriceras, Genotype, *Am. victoris* Dumortier (p. 293).

(*e*) Concerning some of Wright's figured Ammonites.

To Vol. iii of the 'Proceedings of the Cotteswold Naturalists' Field Club,' parts 2 & 3, published in the years 1864–1865, Wright contributed a paper 'On the Ammonites of the Lias Formation' (pp. 162–79, 235–45) describing various species illustrated in four quarto plates, drawn by J. W. Salter. In his subsequent Monograph he makes no reference to this prior work; and yet the descriptions therein of the species concerned are almost word for word identical—just a few alterations like millimetres for inches, changing one technical term for another, and occasionally a few additional remarks; while the figures of the species are in very many cases apparently not redrawn from the specimen, but merely copies of the illustrations in the prior paper.

The search for information as to the localities of certain of Wright's specimens, in connexion with the discussion on the Bredon fauna referred to above (p. 312), led to the discovery that the Cotteswold Club paper was important for the understanding of Wright's Monograph, for the identification of some of his species, and for the recognition of some of his figured specimens, several of which do not seem to have been found. Therefore I append the following notes, commencing with a list of the species figured in the Cotteswold Club paper, marking those which are refigured in the Monograph.

TABLE XX.—COMPARISON OF FIGURES.

Species.	Cotteswold Club paper. Pl.	fig.	Monograph. Pl.	fig.
A. planorbis	i,	1, 1 *a*, 1 *b*.		
A. bucklandi	i,	2, 2 *a*.	i,	1–3.
A. birchii......................	i,	3.	xxxii,	5, 6.
Do. do.	i,	3 *a*.	xxxii,	7.
Do. do.	i,	3 *b*.	xxxii,	8.
A. angulatus	i,	4, 5.		
A. sauzeanus	ii,	1 *a*, *b*, *c*.	viii,	1–3.
Do. do.	ii,	1 *d*.	viii,	5.
A. semicostatus	ii,	2, 3.		
A. turneri	ii,	4.	xii,	1, 2.
Do. do.	ii,	4 *a*.	xii,	5.
Do. do.	ii,	4 *b*.	xii,	6.
A. brookii	ii,	5 side.	vi,	4.
Do. do.	ii,	5 front.		
Do. do.	ii,	5 *a*.	vi,	5.
A. rotiformis	iii,	1.	v,	4.
Do. do.	iii,	1 *a*.		
A. conybeari	iii,	2, 3.	ii,	1, 2.
Do. do.	iii,	3 *a*.	ii,	3.
A. obtusus	iv,	1 *a*, 1 *b*.	xxi,	1, 2.
Do. do.	iv,	1 *c*.	xxi,	5 ?
A. multicostatus .... (*A. bisulcatus* in text).	iv,	2 *a*, 2 *b*, 2 *c*.		

A. bucklandi.—Same figures in Mon. as C. C. paper, just under half of the natural size. Thickness of whorl given by Wright in text in both cases =33 per cent., but figure shows only 25·5.

A. birchii.—Mon. figs. appear to be tracings of C. C. figs.: there is the same omission in both—failure to show inner row of tubercles in front view. The suture-line is said to be from a Bredon specimen. The point was whether figs. 5 & 6 represented a specimen from this locality, and if it was of the natural size what it could be. I come to the conclusion that it is from Lyme Regis and is a large shell reduced, on these grounds:—

In the C. C. paper, p. 179, Wright says, 'The finest specimens of this shell are found near Charmouth and Lyme Regis.' On p. 178 he gives the 'transverse diameter of a large specimen 8 inches,' and the proportions he gives work out as 203, 19, 21·5, —; he also mentions that the shell has 7 turns and 32 to 34 lateral costæ. The C. C. example has 7 turns, has 33 spines on outer row of last whorl, and the proportions of the figure are 84, 22, 18 (22), 61. I think that the figure represents the 8-inch example reduced—the dimensions of aperture transposed by Wright—and that when he transferred the figures to the Mon. he called it, in error, a small shell. It will be interesting to see where this leads.

In the Mon. Wright describes (p. 332) his large specimen as 160 mm. diam., and the proportions that he gives work out as 160, 22, 22, 60. The figure, however, is 166, 22, 23, 58. He goes

on to describe, not this specimen, but his large example of 8 inches in diameter as in the C. C. paper, though occasionally referring to the figures of pl. xxiii—the 160 (166) mm. or $6\frac{1}{2}$-inch specimen.

In regard to the figs. in pl. xxxii he says 'Small specimen Pl. xxxii, figs. 5–8 [5, 6], Diameter 80 mm.,' and so on—the proportions which he gives work out as 80, 19, 19, 62, though the fig. gives 83, 22, 18, 61. It might be urged from this that Wright must have measured from the actual specimen, and not from the C. C. figs. But, in view of what comes out in other cases, this fact of the measurement hardly carries the weight that it might. Suppose, however, that this be accepted—that this specimen was a small one—it leads to curious difficulties. The specimen certainly does not show what Wright figured it for in the Monograph—'that *Ægoceras Birchii* maintained its original form and structure through the various phases of its life'—Explanation of pl. xxxii. For the shell shows that if small it could not possibly be a young *birchi*. It has the proportions of an adult. To be a young *birchi* it would have to show no more than 6 turns at this diameter, only about 23 spines on the outer row of the outer whorl, and proportions 83, 27, —, 53. Also it should show a smooth stage up to half an inch in diameter, as Wright says in his C. C. paper—his figure shows only a smooth stage up to about a fifth of an inch in diameter, which would be correct for a shell reduced to less than half.

If, however, this be not a young *birchi*, but is still figured of natural size, then it must be regarded as a development of *birchi* which has taken on the characters of adult *birchi* at a smaller size—an instance of acceleration or tachygenesis. That it shows so exactly the number of turns, the width of umbilicus, the narrow whorl of an adult, that it has kept exactly the number of tubercles—33—on outer row of last whorl, that it shows no change in character of tubercles, no further differentiation between outer and inner rows of tubercles, no sign of degeneration, and no change except a degree of whorl-compression which might be found to a great extent in a specimen of 203 mm. as compared with one of 160 mm., strains credulity too greatly. That a small shell, being a morphic representative of an adult, and necessarily as a development of it separated from that adult by a very great number of generations, should yet be almost a photographic likeness of the adult, is a degree of similarity in morphic representation which seems far too exact.

I think, therefore, that Wright's C. C. fig. of *Ammonites birchii* which he reproduced in his Monograph as a small shell, is really his large 8-inch example figured less than half natural size, that it is only understandable on that basis, and that therefore it is from Lyme Regis and not from Bredon. At any rate the 8-inch *birchi* which Wright described in his C. C. paper ought to be still in existence, and Curators would be well advised to look out for it.

A. sauzeanus.—The large specimen is said to be of the natural size—Explanation of pl. viii of Mon.; it is actually ×0·7. It is figured half of the natural size in C. C. Diameter there given as 8 inches, in Mon. as 205 mm.

The small shell is said to be of the natural size in Mon. It is figured ×0·73 of this in C. C. paper.

A. turneri.—Shell figured of reduced size, ×0·7, in C. C., but same side shows nearly all inner whorls as missing. Same proportions given in C. C. & Mon. In C. C. fig. 4 *a* is described as 'Quenstedt's figure of the septa.' Explan. of Plate. In Mon. fig. 5 is an exact copy but enlarged, apparently from Bredon specimen (p. 292).

A. brooki.—'Dimensions.—Transverse diameter $5\frac{1}{2}$ inches [140 mm.]; height of outer whorl at the aperture, $2\frac{2}{10}$ inches [56 mm.]; width $1\frac{1}{2}$ inch [38 mm.].' C. C. p. 174. In Mon. 140 mm. 55 mm. 40 mm. Shell figured 0·65 in C. C. paper and front view given—a detail lacking in Mon. Fig. 5 *a* in C. C. 'lobes and saddles from Zieten' (Explan. of Plate). Fig. 5 in Mon., copy of C. C., 'foliations . . . from another specimen . . . My Collection.'

A. rotiformis.—Specimen figured in C. C. paper, peripheral view only, '$\frac{1}{2}$ nat. size' inscribed on Plate. Diameter (p. 238), 7 inches; therefore figure is ×0·74. Natural size in Mon.

On p. 279, Mon. the sentence 'Compare, for example, the sutures in Pl. iii, fig. 2, with those in Pl. iv, fig. 2' does not refer to Mon., but is understandable from C. C. paper.

A. conybeari.—In C. C. '$\frac{1}{2}$ nat. size' inscribed on Pl. Figure 175, 19, 20, 64·5. Dimensions (p. 236): $10\frac{1}{4}$ inches, 2 inches, 2 inches = T. 260, 19·5, 19·5, —, figured therefore ×0·67. Same figs. same size in Mon.; but Wright (p. 273) gives dimensions 340 mm. ($13\frac{3}{8}$ inches), 60 mm., 68 mm., —, = T. 340, 17·5, 20, —. Wright has roughly doubled the diameter of the C. C. fig. instead of giving the dimensions of his text. Loc. Weston, C. C. p. 236, Salford, Mon. p. 273, Saltford, Expl. Pl. ii.

A. obtusus.—Inscribed on C. C. pl. '$\frac{2}{3}$ nat. size,' shows a contracted umbilicus and inner whorls wanting or hidden in matrix. Dimensions not given in C. C. Same figures, same size given in Mon., but with more open umbilicus showing inner whorls. 'Nat. size' in Explanation of pl. xxi. Dimensions in Mon. (p. 293) 155 mm., 65 mm., 58 mm., 55 mm. This makes figs. ×0·70. Figures in C. C. and Mon. do not agree one with the other, nor with the text as regards proportions.

A. multicostatus.—In text C. C., p. 240, '*A. bisulcatus*.' The figure of C. C. not reproduced in Mon. In C. C. 'Dimensions.—Transverse diameter 8 inches; height of aperture $2\frac{3}{4}$ inches; width of aperture $2\frac{1}{2}$ inches.' In Mon. p. 276 are the same dimensions turned approximately into millimetres 200, 70, 64, but applied to

a specimen 'Pl. iii, fig. 1,' which figure shows 186, 51, 45 mm. in these cases, comes from another locality, and has different ribbing. The proportions of the C. C. shell are F. 148, 34, 32, 44, T. 203, 34·5, 31, —, and of the Mon. shell, F. 186, 28, 24, 49.

The whole of the article in Mon. is practically that of the C. C. paper. On p. 276 is a reference (footnote) to Vol. iii of the Proceedings of the Cotteswold Club. In the C. C. paper this footnote cited a prior page of Wright's own paper; in Mon. it cites a page to which it has no reference—another paper, already cited in footnote of previous page of Mon.

It will thus be seen that the C. C. paper gives much information necessary to an interpretation of the Monograph; and that there are several specimens figured in that paper which should have been in the Wright collection, and have been lost sight of: Curators should look out for them.

Now, however, comes another point of interest—Wright's C. C. paper and his plates of the year 1864 were known to Reynès in Marseilles within a short time of publication.

The plates of Reynès's Monograph contain (as we know) many original figures, but also many copied from other works. Most of these are easily recognizable, although there are no statements as to source. All the text issued with the work is the small pamphlet edited by Dr. P. de Ronville, introduction dated 1879. In this is the first part of the text of the 'Monographie des Ammonites,' dated 1867, presumably the year in which the Monograph would have been issued, but for the Author's premature death.[1] The preface to this part is dated by Reynès July 14th, 1866. The immediately following Bibliography extends to the year 1864, and under 1863 is '*Wright*, On the Ammonites of the lias formations, London.'

In his pl. xxxvii, figs. 3 & 4, as *A. brooki*, Reynès has slightly reduced copies of Wright's *A. brooki*, C. C. pl. ii, fig. 5; and in his pl. xliii, figs. 6 & 7, Reynès has again as *A. brooki* copies of Wright's *A. turneri* from Bredon, C. C. pl. ii, fig. 2. On the other hand, *Arietites scipionianus*, Wright, pl. xiii, published in 1879, and Reynès's *Ammonites scipionis*, pl. xxviii, figs. 7–9, illustrate the same specimen; and, looking at the identity of details, Wright's plate is presumably a copy of Reynès's plate in existence 10 years earlier, though not formally published until 1879.

It follows from the above remarks, about the specimens reproduced by Reynès from the C. C. paper, that the suggested possible presence of the Barrow-Bredon *Arietites* fauna in the Rhone Basin fails (p. 311), that the isolation of this fauna is thus more remarkable, and that any argument for a chronological difference of these *Arietites* and the Microderocerates of the *inflatum* set is strengthened. It also follows that the difference of ribbing noted for Reynès's figure of *A. brooki* is merely due to reduction in size.

[1] However, his 'Essai Géol. Aveyron.' bears date 1868.

Reduction when not accompanied by a note to that effect is most misleading, as it makes ribs appear unduly approximate. Such reduction may be misleading in other cases in Reynès's figures.

I have not altered what was previously written about these matters, but have appended references to this page.

It is greatly to be desired that some one with access to the material in the Marseilles Museum should issue an explanatory text of Reynès's plates, indicating which are figures of original specimens and their localities, which are copies and their sources. It would be a grand monument to one who must have possessed an almost unique knowledge of Ammonites, and a fitting accompaniment to a wonderful series of plates. It would help to repair the loss which science undoubtedly sustained in the premature death of an author who gave promise of discriminative ability much in advance of his time.

[Since this paper was read I have found that Neumayr made much the same suggestion, in his review of the work (Neues Jahrbuch f. Min. etc., 1880, vol. ii, Referate, p. 394).]

EXPLANATION OF PLATES XXVI–XXXI.

[All figures are of the natural size, unless otherwise stated. All specimens are in the Author's collection, unless otherwise stated.]

Plate XXVI.

Figs. 1 *a*–2 *b*. *Leptaleoceras leptum*, sp. nov., p. 285.

Fig. 1 *a*. Side view; fig. 1 *b*, apertural view. Holotype from Marlstone, South Petherton (Somerset) [Domerian, pre-*gibbosa*]; ex coll. D. S. Darell. Figs. 2 *a* & 2 *b*. Same views of a young shell from Middle Lias, Gretton, Winchcomb (Gloucestershire); pres. J. G. Hamling.

Figs. 3 *a* & 3 *b*. *Leptaleoceras* aff. *leptum*, p. 285.

Fig. 3 *a*. Side view; fig. 3 *b*, apertural view. From Middle Lias, Gretton, Winchcomb [Domerian, pre-*gibbosa*]; pres. J. G. Hamling.

Figs. 4 *a*–4 *c*. *Acanthopleuroceras rursicosta*, nom. nov., p. 286.

Fig. 4 *a*. Side view, body-chamber, × 0·5; fig. 4 *b*, whorl-section, × 0·66, taken at the break: left side is somewhat crushed; fig. 4 *c*, view of dorsum of end of last whorl, showing subsidiary costulæ of penultimate whorl. Natural size. From Middle Lias clays, Leckhampton (Gloucestershire) [Hwiccian–Wessexian]; pres. late Rev. F. Smithe.

Plate XXVII.

Figs. 1 *a* & 1 *b*. *Radstockiceras complicatum*, sp. nov., p. 287.

Fig. 1 *a*. Side view, test and carina only on first half-whorl; fig. 1 *b*, peripheral view, first half of outer whorl; both figs. × 0·5. Lower Lias, (Radstock) Somerset; Deiran, *Radstockiceras* η. See also pp. 294–95, figs. 6, 12, 21.

Figs. 2 & 3. *Gleviceras glevense*, nom. nov., p. 289.

Fig. 2. Sectional view of holotype, × 0·5. See Pl. XXVIII, figs. 1 & 2, and p. 294, fig. 5. Fig. 3. Side view of a paratype, a young example, × 2; 'Middle Lias, *raricostatum*,' lower part of Folly Lane Brickyard, Cheltenham (Gloucestershire); Deiran, *Gleviceras η*. See Pl. XXIX, fig. 3, and Pl. XXX, fig. 4, for other illustrations of same example.

Plate XXVIII.

Figs. 1 & 2. *Gleviceras glevense*, nom. nov., p. 289.

Fig. 1. Side view of holotype, × 0·5; Middle Lias, '*raricostatum* hemera,' lower part of Folly Lane Brickyard, Cheltenham (Gloucestershire); Deiran, *Gleviceras η*. For sectional view see Pl. XXVII, fig. 2, and see also fig. 5, p. 294. Fig. 2. Side view (part) of paratype taken as genotype; Lower Lias Shales, Cheltenham, *ex* J. Buckman Coll. ('*Am. greenhoughii*') [Deiran, *leviceras η*]. See also pp. 294–95, figs. 4, 11, 21.

Fig. 3. *Microderoceras inflatum*, sp. nov., p. 305.

Fig. 3. Apertural view, × 0·66. See Pl. XXIX, fig. 1.

Fig. 4. *Arnioceras fortunatum*, sp. nov., p. 301.

Fig. 4. Peripheral view, natural size. See Pl. XXXI, fig. 4.

Plate XXIX.

Fig. 1. *Microderoceras inflatum*, sp. nov., p. 305.

Fig. 1. Side view, × 0·66; Lower Lias, Barrow Gurney (Somerset) [Lymian–Mercian, post-*birchi*]. See Pl. XXVIII, fig. 3.

Figs. 2 *a* & 2 *b*. *Arietites turgescens*, sp. nov., p. 296.

Fig. 2 *a*. Side view; fig. 2 *b*, peripheral view showing loss of carina, with long ventral projection and sudden return to a rounded venter with a much shortened rostrum; both figures × 0·5. Lower Lias, Barrow Gurney (Somerset) [Mercian, post-*turneri*]. See Pl. XXXI, fig. 5.

Figs. 3 *a*–3 *c*. *Gleviceras glevense*, nom. nov., p. 289.

Fig. 3 *a*. Side view; fig. 3 *b*, peripheral view; both figs. × 1·25; fig. 3 *c*, part of side view showing suture-lines marked in on photograph, × 2. See also Pl. XXVII, fig. 3, Pl. XXX, fig. 4, for other illustrations of same specimen; also Pl. XXVII, fig. 2 & Pl. XXVIII, figs. 1 2.

Plate XXX.

Figs. 1 *a* & 1 *b*. *Microderoceras depressum*, nom. nov., p. 303.

Fig. 1 *a*. Side view; fig. 1 *b*, apertural view of holotype; Lower Lias, Barrow Gurney (Somerset) [Lymian Mercian, circa *birchi*]; pres. J. W. D. Marshall.

Figs. 2 *a* & 2 *b*. *Microderoceras septigerum*, nom. nov., p. 304.

Fig. 2 *a*. Side view; fig. 2 *b*, apertural view. 'Lower Lias Shales, Cheltenham [District],' Gloucestershire, [Bredon, Worcestershire], [Lymian–Mercian, post-*birchi*]; *ex* J. Buckman Coll. ('*Ammonites birchii*').

J. W. Tutcher, Photo.

Bemrose, Collo., Derby.

LEPTALEOCERAS, ACANTHOPLEUROCERAS.

J. W. Tutcher, Photo.

Bemrose, Collo., Derby.

RADSTOCKICERAS, GLEVICERAS.

2.

4.

1. × 0·5

3. × 0·66

J. W. Tutcher, Photo.

Bemrose, Collo, Derby.

GLEVICERAS, MICRODEROCERAS, ARIETITES.

J. W. Tutcher, Photo. Bemrose, Collo., Derby.

MICRODEROCERAS, ARIETITES, GLEVICERAS.

J. W. Tutcher, Photo.

Bemrose, Collo., Derby.

MICRODEROCERAS, GLEVICERAS.

J. W. Tutcher, Photo.

Bemrose, Collo., Derby.

GLEVICERAS, ARNIOCERAS, ARIETITES.

Figs. 3 *a*–3 *d*. GLEVICERAS RIPARIUM (Oppel), p. 292.

Fig. 3 *a*. Side view, last half of whorl somewhat crushed; fig. 3 *b*, peripheral view of first half of whorl; fig. 3 *c*, peripheral view with ribs, auriculoids, and their connecting pseudo-carina marked diagrammatically; fig. 3 *d*, part of side view with auriculoid marked diagrammatically, also suture-line (approximate): the incipiently-trilobulate superior lateral lobe is on the edge of the periphery in line with auriculoids. All figures × 2. Lower Lias '*oxynotum*,' Aston Cross, Tewkesbury (Gloucestershire) [Deiran, *biferum* η].

Fig. 4. GLEVICERAS GLEVENSE, nom. nov., p. 289.

Fig. 4. Radial line and rib-scheme of example figured in Pl. XXVII, fig. 3, and Pl. XXIX, figs. 3 *a*–3 *c*, marked diagrammatically in photograph, × 2. See also Pl. XXVII, fig. 2 & Pl. XXVIII, figs. 1–2, for illustrations of other examples.

Figs. 5 *a* & 5 *b*. GLEVICERAS AURITULUM/GLEVENSE, p. 291.

Fig. 5 *a*. Suture-line of specimen figured in Pl. XXXI, figs. 1 *a* & 1 *b*, marked in diagrammatically on the photograph; fig. 5 *b*, rib-scheme with auriculoids similarly marked in; both figures × 2.

PLATE XXXI.

[A white × marks the beginning of the body-chamber.]

Figs. 1 *a* & 1 *b*. GLEVICERAS AURITULUM/GLEVENSE, p. 291.

Fig. 1 *a*. Side view; fig. 1 *b*, peripheral view; both figures × 2. From Lias, Charmouth (Dorset) [Bed 92]; Coll. James Francis. [Deiran, *Gleviceras* η.] See Pl. XXX, figs. 5 *a* & 5 *b*.

Figs. 2 *a* & 2 *b*. ARNIOCERAS FLAVUM, nom. nov., p. 298.

Fig. 2 *a*. Side view; fig. 2 *b*, peripheral view; holotype; Lias Limestones, Lyme Regis (Dorset) [Lymian, *Arnioceras* η].

Figs. 3 *a*–3 *d*. ARNIOCERAS ANAGENETICUM, sp. nov., p. 300.

Fig. 3 *a*. Side view; fig. 3 *b*, apertural view; fig. 3 *c*, peripheral view, taken at the end of the whorl, showing ribs, nodes, keel, and incipient sulci—all these figures are of the natural size; fig. 3 *d*, part of whorl, showing suture-lines, × 2. Lias Limestones, Lyme Regis (Dorset) [Lymian, *Arnioceras* η].

Figs. 4 *a* & 4 *b*. ARNIOCERAS FORTUNATUM, sp. nov., p. 301.

Fig. 4 *a*. Side view, natural size; fig. 4 *b*, suture-lines, approximate delineation of last one, not clearly shown, taken at ×. Lias, Paulton, near Radstock (Somerset) [Lymian, *Arnioceras* η]. See Pl. XXVIII, fig. 4.

Fig. 5. ARIETITES TURGESCENS, sp. nov., p. 296.

Fig. 5. Part of periphery, with rib-curves marked diagrammatically, showing change after loss of keel. See Pl. XXIX, figs. 2 *a* & 2 *b*.

DISCUSSION.

Mr. W. D. LANG said that, while heartily welcoming the paper, he would wish to criticize it from two points of view.

(1) In applying the principle of faunal dissimilarity, the

Author appeared to disregard the alternative possibility: namely, that, in certain cases, ammonites may have had very restricted horizontal ranges. It is not enough to point to ammonites as being strongly-swimming organisms. So are fishes: yet many marine fishes are strictly limited in their horizontal distribution. The details of the temperature and currents along the Liassic shore-line were not known sufficiently for us to decide how far the ammonites of any one locality would be restricted; nor did our knowledge of their bionomics enable us to say whether these or other factors might have limited their distribution.

It is extremely improbable that the Oxycones in the *Oxynotus*-Bed of the Dorset Coast are derived, since, with the pyritized specimens are found others, manifestly un-derived, consisting as they do of films on the clay.

(2) Concerning the nomenclature of stages and of zones, two opposing principles are followed by different authors. According to the one, the name of a stage or zone is taken, and its boundaries altered, if desired. According to the other, the original connotation of the term is retained, and, if new divisions are needed, the original stages are subdivided. Thus, Bonarelli subdivided the Charmouthian into Domerian and a lower, unnamed division, which was subsequently termed 'Carixian'; but the Author had meanwhile restricted the term 'Charmouthian' to this lower division, which he now subdivides. Nor was this all, for most of his Raasayan is part of the Sinemurian. Therefore, it would be necessary to say Charmouthian of Mayer-Eymar, Charmouthian of Buckman, and so on. Similarly, Wright instituted a zone of *A. turneri*, but this is by no means the zone of *A. turneri* of the paper now under discussion; and instances might be multiplied.

It would be advantageous if an agreement were to be arrived at among geologists as to which principle should be adopted. The speaker strongly advocated the latter principle, and added that its application should not reach back to old and well-established terms.

Dr. A. M. Davies said that, for nearly thirty years, the Author had been developing ideas on the Jurassic Period in a series of papers in the Society's Journal. Starting with the Inferior Oolite, in which non-sequences could be demonstrated by stratigraphical as well as palæontological evidence, he was now extending this principle in the investigation of strata where only the latter was usually available. While the conditions of deposition of the West European Jurassic were such as to favour local alternations of erosion and deposition, it was possible that some inconsistencies of faunal sequence might be explained in another way—by alternate contraction and expansion of the geographical range of a genus. Even if the Author's explanation should not be confirmed in every case, the Society ought to be grateful to him for bringing so many new facts and suggestions before them; and also, incidentally, for having induced Mr. Tutcher to present them with some of the results of his long and careful work in the Bristol area.

Mr. G. W. Lamplugh said that, while recognizing the scientific value of this intensive study of the Liassic ammonites, he feared that the Author's continued refinements of the nomenclature and zonal classification had carried the subject beyond the reach of the ordinary field-geologist. From the imperfect nature of the evidence, such exactitudes as those shown in the tables could rarely be applicable in the field. The use of fossils by the stratigrapher in the past, though crude, had generally been effective for his purpose; but he could not be expected to master the complicated technicalities of these new methods. The stratigraphical deductions drawn solely from these palæontological studies did not inspire confidence.

Dr. J. W. Evans thought that the questions raised by the paper were of considerable importance, with reference to the problem of determining the time occupied in the deposition of sediments. If the numerous non-sequences believed by the Author to exist were substantiated, there could be little doubt that there must be many more of shorter duration for which no palæontological evidence was available, and the conclusion would be justified that the geological record was of a far more fragmentary character than generally believed, and represented only a small fraction of the time that actually elapsed. In this way would be explained the contrast between the hundreds of millions of years for the age of the Palæozoic formations postulated by workers in the field of radioactivity, and the tens of millions arrived at by those who based their conclusions on the rate of deposition (see Proc. Geol. Assoc. vol. xxiv, 1913, pp. 243–44).

10. *The* Microscopic Material *of the* Bunter Pebble-Beds *of* Nottinghamshire, *and its* Probable Source *of* Origin. By Thomas Harris Burton, F.G.S. (Read May 2nd, 1917.)

Contents.

I. Introduction.

Samples of sand were carefully collected from all the principal exposures on the outcrop of the Pebble-Beds in Nottinghamshire. It was cleaned in hydrochloric acid, sifted, and then separated by means of Thoulet's Solution having a specific gravity of 2·77. Enough of each sample (namely, 2 ounces) was taken to give a heavy residue sufficient to weigh and to mount as permanent objects for the microscope.

II. Physical Characteristics of the Sand.

The sand in the exposures is more or less coherent, in many cases taking on the appearance of hard rock. It may, however, when dislodged (the cement being mainly ferric oxide) be easily crumbled, often between the fingers.

At depths of 102, 211, and 307 feet, cores at the Farnsfield borehole, near the Midland Railway Station, showed the rock to be compact, hard, and very calcareous Microscopic examination proved this to be the only real difference when compared with samples taken from the exposures.

The sand varies in texture and colour, coarse-grained material largely predominating; but the following distinct types may be recognized:—

1. A coarse sand, whitish yellow to buff and brown in colour, found in most exposures.
2. A reddish sand of medium coarseness, found in all the principal exposures.
3. A dark brownish-red sand of fine texture, used for moulding purposes, found especially at Whisker Hill Quarry near Retford, and at Bestwood Warren.[1]

Samples[2] were all taken from No. '2.' Ordinary bedding may

[1] 'The Geology of the Country between Newark & Nottingham' Mem. Geol. Surv. 1908, p. 34.

[2] See map (p. 332) for localities from which sand was collected for separation.

be observed, but false bedding is a marked characteristic of this formation.

The following simple minerals, aggregates, and compound grains have been found:—

SIMPLE MINERALS.

Garnet .... ××	Pyrrhotite ...... ××	Muscovite.
Fluorspar......... ××	Zircon .... ×××	Orthoclase.
Magnetite ...... ××	Rutile .... ××.	Plagioclase.
Quartz.	Anatase .... ×	Microcline.
Tourmaline ...... ×××	Staurolite ...... ×××	Kyanite ..... ×
Apatite .... ×	Sillimanite ...... ×	
Ilmenite .... ×××	Biotite .... ×	

Heavy minerals marked thus:— × occurrence. ×× frequency. ××× abundance.

Mineral aggregates and compound grains include:—Shimmer-aggregates, chloritic aggregates — probably; felsite, cryptoperthite, quartzite, leucoxene, quartz—in addition to decomposed iron-ore, vein-quartz, chert, and schist.

Estimated general constitution of Pebble-Bed sand............		Per cent.
	Quartz	72
	Felspar	25
	Heavy minerals	0·25
	Various	2·75

III. DESCRIPTION OF SOME OF THE SIMPLE MINERALS.

Garnets, mostly of a characteristic pink, appear to be fairly evenly distributed, though they are not very plentiful. Spherical, irregularly-rounded, and angular grains are present, the last-mentioned being the least frequent. Most of the garnets are isotropic, while a few have been observed to be optically anomalous. The largest grain noted was 0·40 mm. in greatest diameter. Generally they are smaller, some considerably so.

Fluorspar is fairly common. The grains are usually angular, isotropic, and colourless. No grains having a greater length than 0·30 mm. have been noted.

Magnetic minerals[1] are fairly frequent, and include magnetite. Other magnetic grains of a yellowish-bronze colour are probably pyrrhotite.

Quartz.—In form these grains are subangular, angular, and well-rounded: the first constitutes the bulk of the quartz. The biggest grains, comparatively few in number, are often apparently perfect spheres. The grains are frequently more or less corroded. Growths of secondary silica on the grains have not been met with. Undulose extinction and other evidences of strain are frequent.

[1] These minerals were removed with an ordinary magnet from samples of uncleaned sand.

The grains are often flattened and smooth. The average maximum diameter of the majority of quartz-grains is about 0·51 mm.

Inclusions are:—(1) Regular; as tourmaline, rutile, apatite, sillimanite, biotite.
(2) Irregular; as gas and fluidal cavities, glass.
(3) Acicular; as tourmaline needles, hair-like inclusions, and fine needles—probably rutile.

Tourmaline, especially the brown kind, occurs abundantly, mainly in the form of more or less rounded grains (a few appear perfectly spherical), and in well-worn, mostly stout prisms. Nearly colourless, blue, green, and mauve grains are present. The blue grains are often very worn and rounded. The average diameter of rounded grains is about 0·24 mm. Frequent inclusions of an opaque mineral without crystal outline occur. Less frequent are fluid, glass, and occasionally rods and needles, resembling sillimanite.

Ilmenite and leucoxene.—The former mineral is plentiful; while the latter is very abundant, and may be derived either from ilmenite or from titaniferous magnetite.[1] Some ore of iron, in most cases decomposed and resembling leucoxene, is attached to quartz, and is quite common. Iron-sand[2] is the most plentiful form in which ilmenite is present.

Micaceous ilmenite occurs sparingly. Its colour is light reddish-brown. The plates enclose rutile-needles, which are interlaced in the form of sagenite at an angle of 60°.

Zircon.—This mineral is abundant, generally colourless, and occurs mostly in well-defined, though more or less worn crystals. Almost spherical grains are not infrequent; a small proportion is unworn. The length ranges from about 0·07 mm. up to 0·30 mm. Some pale-yellow grains resembling monazite, which I take to be zircon, are not uncommon. Inclusions are frequent, consisting of negative crystals, gas-enclosures, and what appears to be apatite.

Rutile is fairly plentiful, and occurs mostly in rounded grains and rather stout, worn prisms. A few grains are fragmentary, but show definite signs of wear. The colour varies from yellow to deep amber-red. Both geniculate and polysynthetic twins are present.

Anatase occurs sparingly. It is found in well-formed plates parallel to (001), also attached to decomposed ilmenite. It varies from colourless to pale yellow. The plates are not worn. The smallest size noted is 0·05 mm., the largest size 0·10 mm.

Staurolite[3] is very abundant. One might almost call it the

[1] J. J. H. Teall, 'British Petrography' 1888, p. 167.
[2] M. F. Heddle, 'Mineralogy of Scotland' vol. ii (1901) Supplem. p. 197.
[3] Excellent figures of some Triassic heavy minerals may be found in Dr. H. H. Thomas's papers, Q. J. G. S. vol. lviii (1902) pls. xxxi–xxxii and *ibid.* vol. lxv (1909) pl. xii.

zone-mineral of this formation. The grains are often rough and angular with frayed and toothed edges, averaging about 0·35 mm. in greatest diameter. Nearly spherical grains occur. Its colour varies from pale yellow, through amber, to reddish-brown. Numerous grains are quite fresh, though some in a more or less decomposed state are present. Among frequent inclusions are opaque black particles, also quartz. Some grains appear to be pure.

The micas.—White mica is plentiful in most places, especially in the eastern outcrop. The flakes are mostly parallel to (001), and exhibit usually a low grey interference-colour between crossed nicols. Strain-shadows are frequent. The average diameter is about 0·53 mm.

A pale-green variety is not uncommon which, in contradistinction to the above white mica, mostly remains dark between crossed nicols.

Biotite, so far as I can determine, is rare.

Felspar is usually found in a very decomposed and clouded state. Orthoclase, which is probably plentiful, may be recognized: strain-shadows are frequent. Only one or two grains of plagioclase have been definitely distinguished. Microcline is not uncommon.

IV. Conclusions as to the probable Direction of the Sediment-bearing Currents, and as to the Sources of the Mineral Grains.

From the distribution of the aforementioned heavy minerals, together with such evidence as the dip of the false bedding and the variation in thickness of the Pebble-Beds, the direction of the chief sediment-bearing currents may be deduced.

From the kind of mineral and the character of certain pebbles, we can reasonably infer the source of origin of much of the material.

The accompanying map and table (p. 332) will help to demonstrate the distribution of the heavy minerals.

Along the western outcrop the highest percentage of heavy minerals, with a specific gravity of 2·77 and upwards, is at Gorsethorpe. From Gorsethorpe a diminution in the percentage is continued northwards, by way of Carburton, to Bawtry. South of Gorsethorpe the fall in the percentage of heavy minerals is continued, by way of Python Hill, to Nottingham.

Along the eastern outcrop we find the highest percentage at Ollerton and Farnsfield. North of Ollerton to Retford there is a considerable decrease; while from Farnsfield to Calverton, in the south, there is a marked diminution in the percentage of heavy minerals.

The current-bedding.—At Retford and Ollerton[1] the prevailing dip of the cross-bedding is in an easterly direction. On

[1] 'The Geology of the Country around Ollerton' Mem. Geol. Surv. 1911, p. 23.

[The white circles indicate the localities from which sand has been obtained for separation purposes. The crosses indicate the position of the bore-holes where the thickest proved parts of the Pebble-Beds occur.]

Table showing the Localities, the Weight in grams, and the Percentage of the Heavy Minerals.

Locality.	*Weight.*	*Percentage.*	*Locality.*	*Weight.*	*Percentage.*
Bawtry	·1386	0·244	Retford	·0602	0·106
Carburton	·1438	0·253	Ollerton	·1560	0·275
Gorsethorpe ...	·3541	0·624	Rufford	·0765	0·134
Python Hill ...	·1536	0·270	Farnsfield	·1530	0·269
Nottingham ...	·1380	0·243	Calverton	·0296	0·052

the Mansfield Southwell branch of the Midland Railway, between Mansfield and Python Hill, 3 or 4 miles of excellent sections show marked cross-bedding dipping south-eastwards.[1]

In the district about Nottingham the dip of the false bedding shows a general direction towards the south-east.[2]

There are subordinate currents which come from the south-west and south-east respectively, as, for example, in the Farnsfield district.[3]

The general direction of the current-bedding is towards the east in the northern part of the county, and veers towards the south-east from the Gorsethorpe district, where the main easterly current bifurcates, as we proceed in the direction of Nottingham.

The thickest part of the formation, as shown by boreholes.—East of the Pennines, as proved by boreholes and shaft-sinkings,[4] the Nottinghamshire Pebble-Beds are thickest at Bevercotes and Kelham, being 568 feet thick at the former, and 471 feet thick at the latter place.[5]

This thickest part is, in the main, in the line of the prevailing currents, indicated by the distribution of the heavy minerals and the general dip of the false bedding (see map and table, p. 332).

'North of Bevercotes the Bunter Pebble-Bed assumes all the characters of the Lower Mottled Sandstone';[6] while south of Thurgarton[7] the entire Bunter, as proved, is thinner than the Pebble-Beds in the localities named above.

The mineral grains and the possible sources of their supply.—The outstanding mineralogical fact is the abundance of staurolite. For this there is no adequate source of supply locally. Ragged patches occur at Sinen Gill—in the Skiddaw Granite series.[8]

I have not been able to discover it in the South Pennines, where I have searched for it in the Cromford neighbourhood of Derbyshire. It appears, however, to be abundant in Scotland, being found in several localities,[9] from Unst in the north-east, roughly in a south-westerly direction to Mull.

[1] 'The Geology of the Country around Ollerton' Mem. Geol. Surv. 1911, p. 22.

[2] 'The Geology of the Country between Newark & Nottingham' *Ibid.* 1908, p. 31.

[3] *Ibid.* 1911, p. 22.

[4] These thicknesses are approximate; but they are the nearest procurable approximations, and, when used for purposes of comparison with known facts in the district in question, are certainly of much interest and importance, if not of exact and accurate evidence in themselves.

[5] 'The Geology of the Country around Ollerton' Mem. Geol. Surv. 1911, p. 18.

[6] W. Gibson, 'The Concealed Coalfield of Yorkshire & Nottinghamshire' 1913, p. 31.

[7] *Ibid.* p. 33.

[8] F. H. Hatch & R. H. Rastall, 'Petrology' vol. ii (1913) p. 248.

[9] M. F. Heddle, 'Mineralogy of Scotland' vol. ii (1901) p. 75 & *ibid.* Supplement, p. 209; G. Barrow, Q. J. G. S. vol. xlix (1893) p. 340 & *ibid.* pp. 349, 350; T. O. Bosworth, Q. J. G. S. vol. lxvi (1910) p. 394.

SYNOPSIS OF THE PRINCIPAL HEAVY MINERALS FROM THE SAND OF TH
AND FROM THE UPPER CARBONIFEROU

[Occurrence represented by ×. Frequency represented by × ×

Rock.........	*Staurolite.*	*Ilmenite.*	*Zircon.*	*Tourmaline.*	*Rutile.*
1. Nottinghamshire.	× × × × Grains very fresh, usually.	× × ×	× × ×	× × ×	× ×
2. Cannock Chase.	× × × Grains often more or less decomposed.	× × ×	× × ×	× × ×	× ×
3. Cheshire	× × Much decomposition of grains.	× × ×	× × ×	× × ×	× ×
4. Cromford neighbourhood —Derbyshire.	......	......	× × × Zircon larger than in the above localities.	× × Much fewer nearly round grains than in the above localities.	× × Generally much larger and more fragmental than in the above localities.

Much the most extensive development in Scotland appears to be that described in the South-East Highlands by Mr. G. Barrow.

It thus seems evident that northern areas were capable of supplying the staurolite.

Shimmer-aggregates,[1] sillimanite, kyanite, ilmenite, and microcline, obviously from metamorphic areas, are most likely, in the main, from the same sources.

'In the Highlands, tourmaline is common and widespread.'[2]

[1] G. Barrow, Q. J. G. S. vol. xlix (1893) p. 340 & pl. xvi, fig. 5.
[2] T. O. Bosworth, *ibid.* vol. lxvi (1910) pp. 394, 395.

UNTER PEBBLE-BEDS OF NOTTINGHAMSHIRE, CANNOCK CHASE, AND CHESHIRE,
EAR CROMFORD IN DERBYSHIRE.

bundance represented by ×××. Great abundance represented by ××××.]

Garnet.	Aggregates.	Leucoxene.	Fluorspar.	Muscovite.	Remarks on lighter material.
××	×××	×××	××	×××	The majority of the quartz-grains are well worn and smoothed; more or less flattened.
××	×××	×××	××	×××	Do.
×	×××	×××	......	×××	Do.
××	×	××××	×	××× Generally rougher than in the above localities; also yellowish, rather than colourless.	The majority of the quartz-grains are irregular, with rough surfaces. Microcline is plentiful among the lighter material.

Dr. Bosworth has informed me that it is found in the bulk of the old Highland rocks. As it is practically certain, as shown by the distribution of the heavy minerals (see p. 332), that the tourmaline has not been mainly derived from southern sources, it is to Scottish areas[1] that we must look for the supply, in larger part, of this mineral.

Tourmaline, as well as rutile, garnet, fluorspar, and zircon, are probably derived, in part, from local sources. As the Carboniferous rocks occurring in the Pebble-Beds (about 4 or 5 per cent.)

[1] M. F. Heddle, 'Mineralogy of Scotland' vol. ii (1901) p. 73; see also 'The Geological Structure of the N.W. Highlands of Scotland' Mem. Geol. Surv. 1907, p. 285.

namely: sandstone, limestone, and chert, have probably been derived from the Pennine ridge, it is reasonable to infer that a small proportion of the heavy minerals are also from the same source. Subordinate currents[1] have also evidently contributed their quota to help to form the Pebble-Beds.

It appears, therefore, that Scotland has furnished the bulk of the staurolite, and of the other heavy minerals associated with it. Tourmaline too, at any rate in greater part, is from northern sources.

How, then, did the foregoing minerals reach Nottinghamshire? To answer this question, it is necessary to compare the material of certain other localities with that under consideration.

The heavy minerals of Cannock Chase, Nottinghamshire, and Cheshire Pebble-Bed sand that I have examined, are substantially identical. They exhibit, on the whole, a marked difference from those of the South Pennine district (see Synopsis, pp. 334–35).

Slices of quartz-felspar grits from the Pebble-Beds of Nottinghamshire and Cannock Chase, also from Loch Torridon, show a striking resemblance one to the other, both macroscopically and microscopically. They are mainly composed of quartz and felspar, with an addition of quartzite, pegmatite, and microcline.[2] The similarity of the Nottinghamshire material to that of Cannock Chase suggests a common source of supply.

To the more numerous and distinctive rocks of the Pebble-Beds of the Midland Bunter, Prof. Bonney ascribes a northern derivation[3]: a north-western river and its tributaries being the means of transport. This north-western river has probably played an important part in the formation of the Nottinghamshire Pebble-Beds. At certain flood-periods, when the supposed river was much fuller than usual, and its outlet and the approaches thereto were probably more or less obstructed by material brought down previously,[4] an overflow occurred. This was probably in the neighbourhood of Macclesfield. The flood-water, with its load of sediment, forced its way across the high land of Derbyshire into Nottinghamshire and the lower-lying lands of the east.[5]

The main current of the overflow postulated above, when it reached Nottinghamshire, bifurcated in the Gorsethorpe district, one branch flowing mainly eastwards by way of the Ollerton district, and the other south-eastwards by way of Farnsfield.

[1] 'The Geology of the Country around Ollerton' Mem. Geol. Surv. 1911, p. 22.

[2] 'The Geological Structure of the N.W. Highlands of Scotland' Mem. Geol. Surv. 1907, p. 285.

[3] Q. J. G. S. vol. lvi (1900) p. 302.

[4] The staurolite of Nottinghamshire is fresher than the staurolite of Cannock Chase and that of Cheshire: this lends support to the above-postulated theory of obstruction. The material in the first instance (long accumulated and weathered) was brought down by the flood-water into the western basin, naturally more or less blocked later, and certain fresher material was similarly brought from the north—much of the latter being carried by the overflow into Nottinghamshire and the eastern lowlands.

[5] A. J. Jukes-Browne, 'Building of the British Isles' 3rd ed. (1911) p. 235.

From the foregoing statements it is evident that the bulk of the material in question was most likely derived from Scottish sources; that the Pennine ridge has certainly supplied a share; and that subordinate currents have probably contributed their small part towards forming the Nottinghamshire Pebble-Beds.

I gratefully acknowledge the obligations that I owe to many for their kind assistance in connexion with this paper, especially to the Rev. Prof. T. G. Bonney, Prof. H. H. Swinnerton, and Dr. H. H. Thomas.

Discussion.

Dr. R. L. Sherlock thought that it was not clear what was meant by the 'Northern Bunter basin.' This might be either west or east of the Pennines. In either case it would be necessary for the north-western river to cross the Pennine ridge, admittedly in existence. Only in times of flood did the river bring sediment through the hills into Nottinghamshire, and yet the bulk of the material was believed by the Author to come from Scotland. The speaker thought that a more local origin for the bulk of the material was probable, and that, until the Carboniferous rocks of the Pennines, and particularly the Millstone Grit, had been searched, it was unsafe to assume that the heavy minerals could not have been obtained locally. One objection to the theory that the bulk of the Bunter material was brought from Scotland had never been answered—it was, that the number of pebbles fell off as the supposed source was approached. The speaker believed that the paper by the late J. Lomas on the Origin of the British Trias explained satisfactorily most of the features of Triassic rocks. On this hypothesis, supported by the work done by the Egyptian Survey, Dr. Wade, and others, the Bunter Pebble-Beds were formed by torrential waters that occasionally swept out wadis, filled with débris produced by desert erosion, and spread the materials over a coastal plain at the foot of the hills. The rock-fragments were not only rounded by mutual battering, but much fine silt was produced which, when dry, was blown into pools and into the Caspian-like sea to form Triassic marls. The chief difficulty was the presence of quartzite-pebbles, but it was possible that these might not have travelled far: say, from the buried pre-Triassic rocks of Charnwood Forest. The quantity of pebbles in the Pebble-Beds of Nottinghamshire was apt to be exaggerated, because they were concentrated in soils and Drift, although in a clean section there were usually quite few stones. Moreover, only a moiety of these were quartzite.

It appeared from a lantern-slide that the Author had not discriminated between the divisions of the Bunter. There are beds in the Lower Mottled Sandstone which have a structure different from that of the Pebble-Beds, and the former were laid down in very shallow water. The sands at Whisker Hill, Retford, one of

the localities collected from, could be described as Upper Mottled Sandstone.

The speaker was interested to find that a belt, containing a high proportion of heavy minerals, extended across the strike of the Bunter opposite Gorsethorpe. This was confirmation of his explanation given some years ago of the origin of the Mansfield Sandstone in the so-called 'Permian' below. The explanation required a river flowing in from the Pennines, in practically the position described by the Author.

The Author was to be congratulated on the work that he had done. It had been customary for geologists to collect Bunter pebbles, and ignore the sands in which they lay. Dr. Thomas had done pioneering work in Devon on these sands, and the Author had now accomplished useful work in another area.

Dr. P. G. H. Boswell remarked that a paper dealing with the petrography of the Bunter deposits was certain to be of considerable interest, and the Author's contribution was clearly no exception to the rule. While the records of detrital mineral assemblages were very valuable, it was obvious that great caution should be exercised in drawing inferences regarding the source of the material. A great deal rested on the number of samples collected, their selection, and their vertical and lateral distribution. With regard to this, he (the speaker) wished to utter two words of warning, which might, however, be unnecessary in the case of the paper under discussion.

The variation in the percentage weight of the heavy mineral residue did not necessarily give any indication of the source of the material. It was now an established fact that the heavy crop increased with the decrease in grade-size in sands, and the grade or mixture of grades in every sample must therefore be determined.

In the next place, the presence of minerals of metamorphic origin, such as tourmaline, staurolite, garnets, micas, etc., in sediments did not necessarily indicate origin from metamorphic rocks. Such minerals were frequently the least unstable, and were found in most sedimentary rocks in the British area: some of them might have passed through several geological cycles, and have been derived directly from older sediments.

Mr. Bernard Smith was of opinion that the chief value of the Author's work consisted in his careful and useful determination of the mineral residues, but that much more work of a similar nature must be undertaken before such broad conclusions could be drawn with safety. He emphasized the fact, which he himself had been the first to put on record, that at Farnsfield the direction of dip of the cross-bedding was roughly from south to north, swinging now to the west and now to the east. While agreeing in general with the objections raised by Dr. Sherlock, the speaker was not prepared to follow him in suggesting that the Pebble-Beds were accumulated by river-action on an exposed coastal shelf, but considered that they were deposited in shallow water. The pebbles appear to have entered the district from the south, but probably

most of the finer material was derived from the Millstone Grit or Coal-Measure sandstones of the neighbouring Pennine Range, the existence of which is indicated by the occurrence—between Dale in Derbyshire and Lenton near Nottingham—of Bunter sandstone banked against cliffs of Coal-Measure sandstone that were subjected to atmospheric weathering at that time. An examination of the heavy minerals of these rocks should throw considerable light upon the origin of the Bunter.

Mr. W. H. Booth stated that a boring made at Farnsfield, some twenty-two years ago, entered the Waterstones, and the water-level was within a few feet of the surface, the rocks being therefore fully submerged. A little later, a deep borehole was put down at Newark-on-Trent at Messrs. Hole & Company's brewery. It was taken to about 800 feet by the Diamond Boring Company, and the water rose to 50 feet above the surface. If still in existence, the sample-box of the Farnsfield core would be in the hands of the contractors, Messrs. Le Grand & Sutcliff.

Dr. Herbert H. Thomas, in reply, thought that there was great difficulty in ascribing a local origin to much of the Triassic material. The presence of staurolite in such great abundance was difficult to explain on that hypothesis, and he considered it even more dangerous to speculate on the nature of rocks completely hidden by the Trias, than to point to areas known to be capable of supplying material similar to that of which the Triassic rocks are composed.

He expressed the opinion that certain minerals mentioned by the Author, more especially the staurolite, had been derived directly from metamorphic rocks, and had not before entered into the composition of a detrital rock.

He felt sure that the Author, if he had been present, would have been pleased with the reception accorded to the paper, and with the interesting discussion to which it had given rise.

[December 31st, 1918.]

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